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ABSTRACT

This manual is designed to provide support for workshop leaders--science supervisors, staff developers, principals, school change agents, and university instructors--who work with preservice and inservice teachers. The goal of the project was to develop a series of workshops that could support teachers of grades four to six as they shift to an increasingly hands-on, project-based approach to science learning enhanced with technologies such as telecommunications and microcomputer-based laboratories. Topics include Reflecting on Practice, Microcomputer-Based Laboratories, Telecommunications, and Bridging to the Classroom. Resource materials for science background, technology background, and other useful information are also included. Contains approximately 70 references. (JRH)

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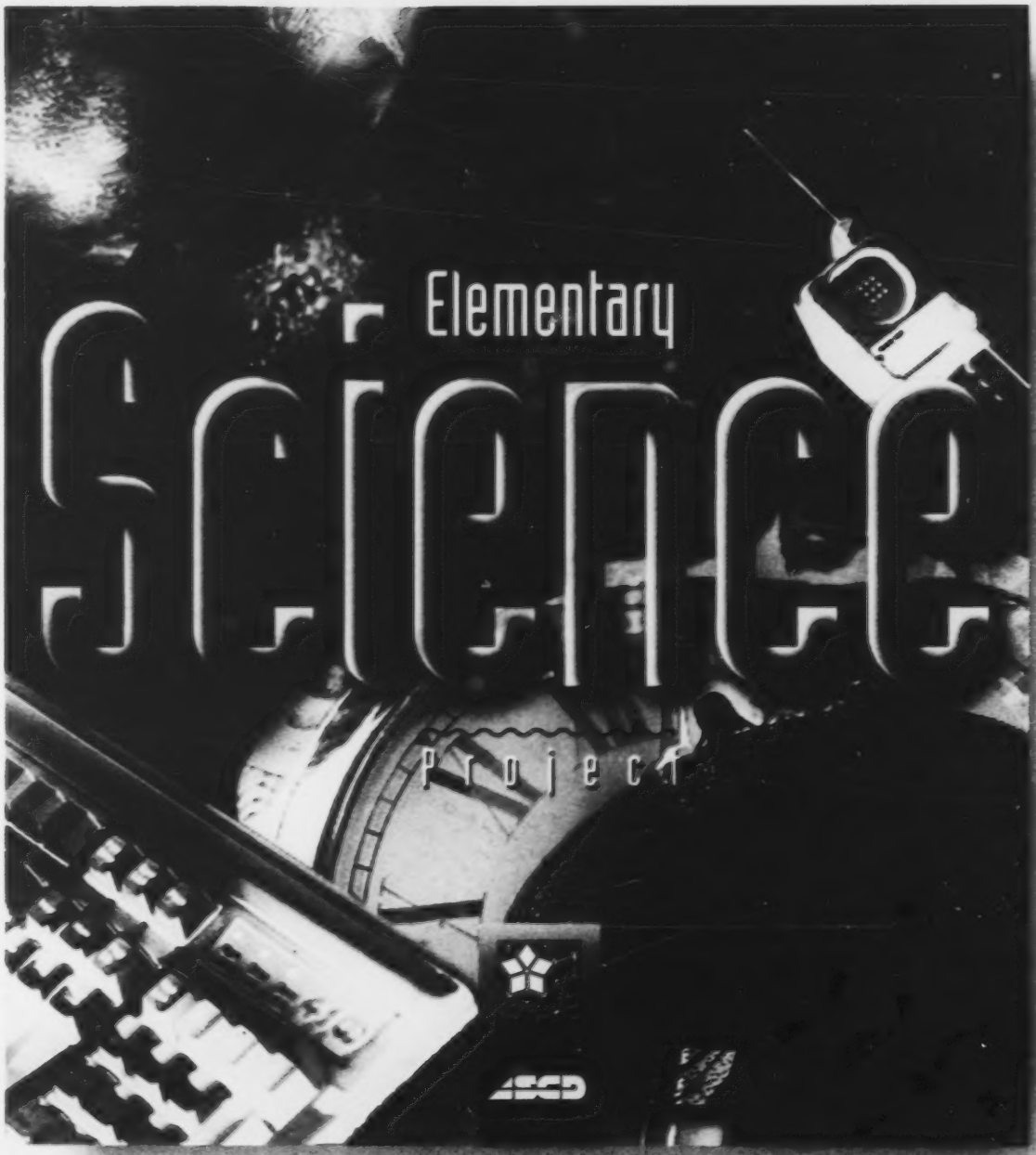

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Leader's Manual

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TERC is a private, nonprofit research and development corporation dedicated to hands-on mathematics and science learning. For more information, contact TERC Communications, 2067 Massachusetts Avenue, Cambridge, MA 02140.

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See page 12 for information on the structure of this book and how to design workshops using various activities.

Activity Sheets are included within each activity module. The activities are designed so that you can take them out of the notebook and reorder them to suit your workshop plans.

Resource materials for science background, technology background, and other useful information are located in the back of the book. These may be reproduced as handouts for teachers who attend your workshops.

Resource Material

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Project Perspective

History of the Hands-On Elementary Science Project

The materials in this manual were developed and tested as part of a two-year grant from the U.S. Department of Education Fund for Innovation in Education. The goal of the project was to develop a series of workshops that could support teachers of grades four through six as they shift to an increasingly hands-on, project-based approach to science learning enhanced with technologies such as telecommunications and microcomputer-based laboratories (MBL).

TERC presented workshops to staff developers during the summers of 1992 and 1993. These developers in turn adapted activities, presented workshops and provided ongoing support to teachers (including Chapter 1) across the country. Project staff and our cadre of trainers kept in touch during the school year through follow-on workshops, phone calls, site visits and telecommunications. Out of the wealth of feedback, data, thoughts and questions of our trainers and their participating teachers, we have created this manual and accompanying video for leading teacher workshops.

Audience for This Manual

The Hands-On Elementary Science manual and video are designed to provide support for workshop leaders—science supervisors, staff developers, principals, school change agents and university instructors who work with preservice and inservice teachers. We expect that the materials will be used flexibly, and that workshop leaders will choose, order and modify workshop activities in ways that work best for them and their participants.

Goals of the Project and the Workshops

Through Hands-On Elementary Science workshop experiences, elementary educators will address the following issues:

What is project-based science?

What does project work look and feel like?

What is the role of the learner's ideas?

What is the role of questions? How do you support learners in asking questions?

What is the role of technology in supporting project work?

What is the role of collaboration?

What is the role of reflection?

What is the role of the teacher in project-based science?

What can project-based science look like in the classroom?

How do you maintain academic rigor when you open up the learning experience?

How do you assess project-based science learning?

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Our Ideas About Learners and Learning Science

If we think about our own school science experiences, what may come to mind are memories of thick textbooks, formulas and specific facts that we were expected to remember. In contrast, our view of what school science should be today has students actively involved in doing science — working collaboratively with others, posing questions, designing and carrying out investigations, and reflecting on findings and procedures.

Learning is an active process in which we construct our views of how the world works. Beginning with existing ideas, we change, modify and extend understandings based on the experiences we have. It helps to have opportunity to reflect on our experiences and understandings, and to be able to talk with others about our ideas.

As we make provisions for learners to do science in the classroom, we need to keep these ideas about learning in mind. A project-based approach to science supports this view of learning by providing sustained opportunity for students to explore ideas. A central goal of this approach is to introduce students to asking questions and developing their own strategies for addressing those questions.

one can familiarize him (the child) with a few phenomena in such a way as to catch his interest, to let him raise and answer his own questions, to let him realize that his ideas are significant.

— E. Duckworth,
The Having of Wonderful Ideas 1978

Our Ideas About Teachers as Learners

Teachers are also learners — learners of practice. If we are to support their efforts to teach science well, we need to provide forums in which they can do science in new ways, reflect on their own learning and consider implications for their own classrooms. If current theory is to reach the classroom, teachers must have more than awareness of current ideas. They must have action knowledge that can only come from experiencing active learning themselves.

Each workshop activity is an exemplar of the kind of learning environment we are hoping teachers will create in their own classrooms. The activities embody both process and relevant science content. Teachers reflect on their own learning in the context of their own project work in order to transfer it meaningfully to classroom practice.

Bringing about change is very difficult and slow — it takes years. Through sustained support at the local level, teachers and trainers can begin to form a community of practitioners effecting long-term change in elementary science.

We believe it is essential that teachers experience project-based science learning themselves. Our suggested workshop activities are in response to our concerns about how to construct understanding of teaching and learning.

TERC Staff

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What is Project-Based Science?

There are many different perceptions of what we are talking about when we use terms like project-based science or constructivist learning or open-ended science activities. One important goal of this manual is to provide a platform for a discussion of issues that arise around these terms. Indeed, there are various commonly used, related terms, such as: open-ended work, student-directed investigations, inquiry learning, discovery learning, hands-on science, constructivism and sense-making in science. They involve a child-centered approach, a concern with science process as well as fact and an emphasis on problem solving.

These approaches are often contrasted with didactic teaching using textbooks and prescriptive worksheets. We recognize that ultimately the learner is responsible for asking questions and designing an investigation to address those questions. But if learners (teacher or student) is only familiar with a didactic, memorization-based approach to science, that learner will need support in shifting his or her understanding of what science is as a process.

Our ideas about project-based science have evolved through several years experience developing innovative science curricula, software, and hardware. Through our work on the Hands-On Elementary Science project, we have developed an instructional model for project-based science (see diagram).

While the model may oversimplify the notion of project work, it represents our "sense-making" at this time.

"The formulation of a problem," said Einstein, "is often more essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old questions from a new angle, requires creative imagination and marks real advances in science."

— A. Einstein and L. Infeld,
The Evolution of Physics, 1938

"We are not the only experimenters here. For it is the children who must become in all truth experimenters. Not good listeners, not quick memorizers, not people facilely following clear directions to a seen and given end, but real experimenters, testing nature and themselves with questions born of wonder and reared in understanding.

Sometimes the style and emphasis we are describing is characterized, too patly, as the 'discovery method.' The child is thought to discover for himself the results which we want him to acquire. There is something in this name, but it is too simple. Our emphasis is not really on discovery, but on the way of discovering. More closely, it is the 'inquiry method.' The concrete materials, their gradually more skilled and directed use, their recombination as suggested by experience — these are certainly the paths to the discovery.... Any study of science that does not allow the possibility of a discovery is a stultifying one, above all at introductory levels. In this sense the term is apt. There is some truth, too, in the word-play of calling the work 're-search' instead of research."

Philip Morrison, *The Elementary Science Study — A History*, 1973

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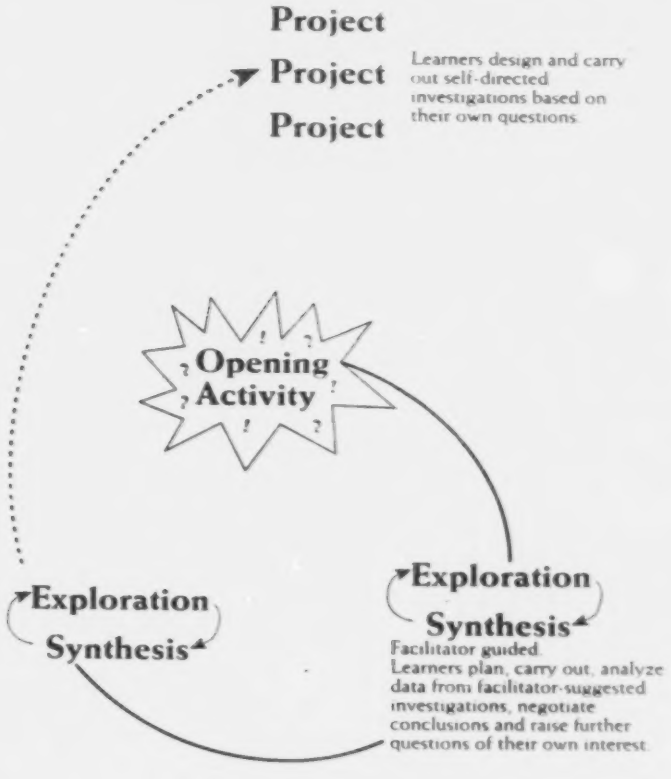
The Hands-On Elementary Science Instructional Model of Project-Based Science



Project work evolves from facilitator-initiated to participant-initiated. Project work may or may not be collaborative. Technology is used as a tool to support the learner as appropriate. In project-based science, both content and process are integral.

In our model, a facilitator engages learners in a science process and guides them through an investigation and synthesis. During this cycle, the initiative and direction shifts from the facilitator to the learner. By the time learners have experienced one or two facilitated investigations, they are ready to ask their own questions and pursue their own investigations, using their peers and the facilitator as resources and guides.

Resource Material

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Scientific Process and Process Skills

How do scientists do science? Is there a sequence to their work? We may think of an investigation as progressing in an ordered manner, but in reality, the process often starts by "messing around" with a phenomenon and asking quick "what if" questions.

As learners do science, they experience the cyclical nature of science and employ skills that scientists use in their work. These are skills that help the learner to learn directly from objects and events — raising questions, hypothesizing, planning investigations, making observations, measuring — and skills that help the learner to represent and make meaning of data — recording, interpreting, reflecting critically, posing new questions.

There is nothing more central to a discipline than its way of thinking. There is nothing more important to its teaching than to provide the child the earliest opportunity to learn that way of thinking.

— Jerome Bruner,
Toward a Theory of Instruction, 1966

Science as a Social Activity

Learning cannot be separated from the social interactions in which individuals are engaged. Learning has been described as moving from understanding with the help of another to internalized, individual understanding; moving from being regulated by others to regulating oneself (Vygotsky, 1978).

"One setting that allows social interactions to function as the source of intellectual change is group work on projects. The joint goals and shared problems of such a project require negotiated solutions. Hearing one learner articulate the problem can help another see it more clearly. Hearing someone else's misunderstanding can help a learner see a better way into a problem" (Weir, 1989). As a group works together on a project, the group members negotiate solutions and develop a shared understanding, based on their observations and data interpretation. The need to justify a conclusion to others leads to a better understanding of the phenomenon.

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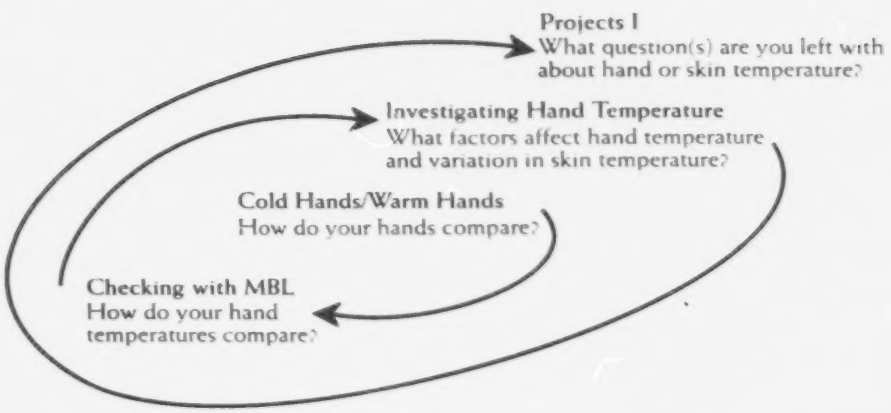
Scientific Process: One Model


Projects I
What question(s) are you left with about hand or skin temperature?
Investigating Hand Temperature
What factors affect hand temperature and variation in skin temperature?
Cold Hands/Warm Hands
How do your hands compare?
Checking with MBL
How do your hand temperatures compare?

Art or Science?

When the artist is alive in any person, whatever his kind of work may be, he becomes an inventive, searching, daring, self-expressive creature. He becomes interesting to other people. He disturbs, upsets, enlightens and opens ways for a better understanding. Where those who are not artists are trying to close the book, he opens it and shows there are still more pages possible.

Robert Henri,
The Art Spirit, 1923

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Technology in Support of Science Learning

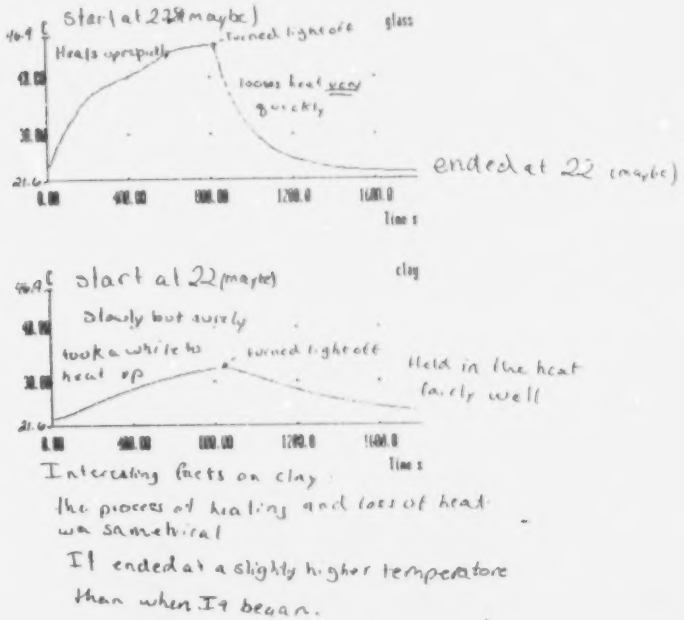
Technologies such as microcomputer-based laboratories (MBL) and telecommunications are powerful tools for supporting project-based science. These technologies help learners gather and represent data, share ideas and work collaboratively. By using technology to facilitate repetitious procedural tasks, learners can focus on the underlying concepts and processes of the phenomenon they are studying. In the Hands-On Elementary Science workshops, participants are introduced to MBL and/or telecommunications in the context of a science investigation — they learn how to apply these technologies in support of project-based science learning and how to find out more about the technology when they need to know it.

Microcomputer-Based Laboratories

MBLs simplify the process of gathering and representing data. Learners quickly obtain evidence related to their questions and are able to pose more "what if" questions. MBLs also broaden the range of data that is accessible to learners, from data collected over very short time intervals (recording the temperature every second) to collecting data over an extended period of time (recording the temperature every minute over a 24–hour period). Because the MBL graphs data in real time, learners can make a connection between the phenomenon and its graphic representation. Their ability to correctly interpret line graphs improves dramatically with MBL use (Tinker & Mokros, Brassel). Users also choose the type of graph (line, bar, data points) that will display their data. This feature helps learners determine what

What we did:
We put light right on the rim of the cup.
We turned the light off at 800 seconds.
Our goal was to see what held the heat better.
Conclusion:
Clay.
Interesting facts on glass:
Heated up fast but shakily.
Lost heat smoothly.
The ending temperature was lower than starting temperature.
Interesting facts on clay:
The process of heating and loss of heat were symmetrical.
It ended at a slightly higher temperature than when it began.

— 5th grade student


start at 22 (maybe)
glass
Heats up rapidly
Turned light off
loses heat very quickly
ended at 22 (maybe)
Time s
start at 22 (maybe)
clay
Slowly but surely
took a while to heat up
turned light off
Held in the heat fairly well
Time s
Interesting facts on clay:
the process of heating and loss of heat was symetrical
It ended at a slightly higher temperature than when It began.

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representations best display certain kinds of science phenomena.

Telecommunications

The principal power and potential of telecommunications is twofold. It supports long-distance research and collaboration and provides access to a vast — sometimes overwhelming — wealth of resources and information.

For elementary science students, telecommunications-mediated collaborations provide an opportunity to share research explorations and results with an audience of fellow students; students' writing improves when they are communicating with peers (Cohen & Riel, 1989). Telecommunications can make available a variety of resources and information, such as news, weather data or ERIC (Educational Resources Information Center). It provides students with access to a geographically distributed data pool, either regional or national. And the built-in time lag between communications provides an opportunity for students to conduct investigations offline and to reflect on their learning as they prepare to communicate their work.

For the elementary science teacher, telecommunications can provide access to a professional community of practice, breaking down the isolation of the individual in his or her classroom. It may offer access to developers, researchers and scientists who are interested in working with teachers to improve science education, and it can provide access to an array of information resources on both education and science as well as the opportunity for both teachers and students to participate in network-mediated science projects.

A turning point came for me in the early 1960s, when computers changed the fabric of my own work. What struck me the most forcibly was that certain problems that had been abstract and hard to grasp became concrete and transparent, and certain projects that had seemed interesting but too complex to undertake became manageable.

— Seymour Papert,
The Children's Machine, 1993

Message posted on the Hands-On Elementary Science bulletin board on America Online

Subj: Spring Visit 93-05-26 20:36:58 EDT
From: Rkopicko

Since several of the Kids Network units use temperature measurements the use of an MBL probe would be helpful and a real motivation for students. I agree with Jim that fourth graders could handle the technology. I wouldn't be a bit surprised if the same fourth graders could help motivate their teachers to use the probes as the tool of choice when you need an accurate temp reading!

This is great — nice to be here!

Robert Kopicko
West Bloomfield, Michigan

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Recommendations to Workshop Leaders

Your role as coordinator and facilitator of a Hands-On Elementary Science workshop may be somewhat different than for other workshops. The use of MBL and telecommunications technology, and the emphasis upon learning at the teacher's level, with challenging problems, hands-on experiences and reflection on practice, ask that you become a catalyst, troubleshooter and raiser of issues. On a practical level, running hands-on workshops and supporting long-term teacher change is quite different than running a typical afternoon in-service program. Expect that your understandings and approach to elementary science will change along with that of the teachers (and their students)!

The following information encapsulates some of the major considerations we have encountered in piloting the workshop.

Planning Your Workshop

Design a sustained implementation strategy. Alternative structures, extended time frames and fewer participants may result in more effective workshops. The one-shot workshop does not produce broad and sustained change. Alternatives might include: a workshop that meets regularly over several months or several years, a teacher study group or direct work with teachers in the classroom. See *Sample Implementation Strategies* in the Resource Materials for ideas.

The participants will need individual support during the workshop. Consider a leader-to-participant ratio of 1:12 or less.

Allow double the time. A technology-enhanced workshop will take much more preparation time. If you are bringing computers to the site, anticipate additional time for set-up. Bring extra pieces of equipment, extension cords, power switches. For some mysterious reason, equipment may not work when moved to a new site. When possible solicit the help of a technology support person. Finally, consider what you will do if one or more setups do not work.

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Conducting the Workshop

Set an expectation of involvement. Tell participants that you want them to be involved in their own learning. By slowing the pace and not overcrowding the workshop, you are more likely to create sustained focus on the learning experience. There is always tension between giving participants as much information as possible and making the experience meaningful. The workshop is a unique time for participants to focus on their own learning. You can always distribute information to participants in written form at another time.

Trust the participants' ability to lead their own learning. Workshop time is limited and providing time for extended projects may seem impractical, but we have found that when we ask participants to pursue a question of relevance to them without structuring exactly how they will handle the challenge, then they pick up the responsibility and respond in diverse ways that are rewarding within each group and when shared with the whole group.

Communicate your rationale. Clarify what you are doing and why you are doing it in a certain way. Provide an agenda. Failure to do this can be a barrier for some participants that prevents or inhibits their involvement in the activities.

Provide time to reflect. Doing is not enough. Participants need to process their experiences and discuss implications for their own classroom.

Help teachers bridge to their classroom. The last set of activities in this manual is designed to help teachers make a transition from the workshop to the classroom. Send participants off with a task to ensure that ideas from the workshop will be tested. Be sure to establish a way for participants to share these experiences. Where possible, provide follow-up support in the classroom.

Teachers may need considerable support and guidance to enable them to redefine their ideas about how children learn, what science education is, and what their role as teachers should be.

— Fred Biddulph, David Symington and Roger Osborne, *The Place of Children's Questions in Primary Science Education, 1986*

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Designing a Workshop

This manual is set out in roughly the structure we recommend for a workshop or a longer series of workshops. Teachers first consider their ideas about hands-on elementary science teaching and learning. Then, they engage in their own learning through one or several opening activities and explorations. After teachers have had experience with both science content and the particular technologies, they choose their own questions to investigate, design and conduct their own projects. Finally, teachers consider issues of implementation and design strategies to bring project-based science into their classrooms.

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Resource Material

The Resource Materials provide background information on science concepts, MBL, telecommunications and other resources. The gray pages provide information to you or your teachers and are for photocopying. Look for the Resource Material icon in the activity to guide you to supporting pages.

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Sample Plans for a One-Day Workshop and Follow-Up Sessions

Sample Hot Cars Activity Schedule

10 Minutes	Break into small groups. Read your LAN Welcome message. **Reply to all stations**: Your names and the name of your station.
25 Minutes	Discuss within your small group the Hot Cars challenge.
30 Minutes	**Network messages**: Exchange ideas about the Hot Car challenge. Generate a list of factors that seem relevant. Negotiate which factor each group will test.
60 Minutes	Collect data, graph as appropriate and analyze.
BREAK (Lunch)	
30 Minutes	Network **messages**: Share test results.
45 Minutes	Design your "best heatkeeper" based on the collected test data from each group. This is a paper and pencil task. Your design should only be based on the test data, not including additional knowledge you undoubtedly have.
45 Minutes	Reconvene as a whole group. Share designs, including the underlying reasoning. Discussion: Science, technology, and learning.
30 Minutes	Group discussion: *How do I implement this in my schools?*

Sample Plans for a One-Week Intensive Workshop

	Mon. 7/12	Tues. 7/13	Wed. 7/14	Thurs. 7/15	Fri. 7/16
8:45 - 9:00	•Coffee & Greetings	•Coffee & Greetings	•Coffee & Greetings	•Coffee & Greetings	•Coffee & Greetings
9:00 - 12:00	•Overview •Watching the Drops •Where is the Science?	•Cooling Works •Where is the Science? •Reflecting on Practice	•Telecommunications: LAN •Trash	•Project Work	•Implications for the Classroom: Modifying a Lesson •Case Study: Supporting Student Learning
12:00 - 12:30	Journal	Journal	Journal	Journal	Journal Sharing
12:30 - 1:30	Lunch	Lunch	Lunch	Lunch	Lunch
1:30 - 4:00	•Reflecting on Practice •Cooling Works	•Telecommunications Online Discussion: WAN •Data Representation	•Where is the Science? •Intro. to Project Work	•Presentations	•Case Study: Teacher Learning •Planning Your Own Workshop

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Overview

Reflecting On Practice

Purpose and Rationale

The Reflecting On Practice (R-O-P) activity was developed to deepen our understanding of project-based science. The aim is to unpack and analyze the underlying issues, so as to help develop a common understanding of what we are talking about. The richness of the R-O-P activity comes from discussion that develops as the exercise is being carried out.

As participants work through the example, they generate assessments which reflect their own views regarding what is implied by project-based activities and what their assumptions are about "good practice."

This activity is adapted from Simon et al., *Open Work in Science: A Review of Existing Practice,* 1992.

Synopsis

Working alone or with a partner, participants read the descriptions prepared by five teachers who describe themselves as carrying out project-based science. These descriptions are to be placed on continua with respect to three criteria.

Participants compile a composite picture of the results. This leads to a discussion as to why there is a wide spread of placements. Emerging from this discussion will be a deeper view of what project-based science is all about.

Participants work in groups to write their own descriptions that better capture for them the components of project-based science. They are invited to invent their own continua when desired. Time: One-half day.

Materials

Handouts:
- Overview of the Activity
- Teacher Descriptions
- R-O-P Continua
- Blank Continua

Chart paper

Markers

Preparation

Draw the three continua on chart paper to compile a composite picture of the results.

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Opening Activity

To begin the process, participants work through an example that provides a framework for looking at various ways in which science activities are structured in today's classrooms. We have found it helpful to use the continual Activity Sheet (page 22) to do an initial analysis of an activity from the workshop (such as Watching the Drops) as a group. This gives everyone a concrete frame of reference for their ideas.

After processing one activity as a whole group, ask participants to form teams and hand out the Activity Sheet: Teacher Descriptions. In the handout, participants will find five descriptions by teachers who do project work in science. Suggest that they examine three of the five. They should read each description and consider it in terms of three criteria:

- *how precise a definition of the problem is provided by the teacher*
- *how closely the process for working on solving the problem is defined by the teacher, and*
- *how open are the problems, i.e., how many solutions are possible.*

The idea is to record each description name where a participant thinks it fits on each continuum. There are no right or wrong answers: these are meant to provide a primer for discussion.

Typically, when faced with this task, some workshop participants complain that they do not have enough data. Ask them to make a decision based on what they have. Reassure the participants that this is only the first stage of the activity and that they will return to the problem later. It is assumed they are going to disagree, but it is important to examine their disagreements. Explain that the exercise will be repeated in relation to other activities during the workshop. Further, ask them to put on hold the question of which places on a continuum are better and which are worse than others. This should not concern them at this stage since it is addressed specifically in the Synthesis.

Exploration

Compile a composite picture of the results. Lead a discussion as to why there is a wide spread of placements. Emerging from this discussion will be a deeper view of what project-based science is about.

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Take a look at the spread of placements for each description, listing the range in each case. Have the participants think about why this is so. What underlies the different ratings?

At this stage, point out that participants are going to be carrying out some hands-on activities during the workshop, each of which will be followed by an R-O-P analysis of that activity.

An example showing how a group of teachers distributed their placements at a recent workshop is shown on page 19.

Synthesis

Rewriting the descriptions: Now ask the participants to work in groups to write their own descriptions that better capture the components of project-based science. Invite them to invent their own continua using the sheet provided.

The continua suggest implicit judgements about good practice. Now is the time to address this issue. For example, one could introduce a continuum that specifically focuses on the quality of the teaching, as follows:

To What Extent Is This Good Science Teaching?

Students learn less — Students learn more

Teaching and the R-O-P: During the whole group discussions that follow, it is important to bring out the differences that were revealed during the analysis. Ask participants to justify particular placements. Their analyses can then become the basis for an extended discussion about the teaching that may include:

- *an in-depth analysis of the many dimensions of project-based learning,*
- *why it is important to think about these dimensions,*
- *how opinions differ about which aspects are crucial and which are secondary,*
- *decisions as to how to take these ideas back to their classrooms, and*
- *how teaching practice will vary from teacher to teacher and from time to time, depending on their aims for their classrooms in given situations.*

The original intention for this activity was to have a continuum which did not necessarily reflect a judgment about what *should* happen in a classroom. In the example, it could be argued that the best classroom

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activity is one in which some structure is provided by the teacher, in which ratings would be placed in the middle of the continuum on *Defining the Problem* or *Choosing the Methods*.

When we tried out this R-O-P activity with a workshop participants, we supplied them with unlabeled continua and invited them to develop their own labels to cover aspects that they considered important. Some of the dimensions they wanted to include were:

- *hands-on, stressing science process skills,*
- *developing cooperative learning strategies,*
- *amount of science involved — i.e., conceptual content,*
- *use of technology, methods of class assessment,*
- *identifying extensions to the activity,*
- *integrating math and science,*

Did this exercise help you think about project-based learning? What insights did you gain, if any?

Providing Opportunities for Cooperative Learning

Never — Always

During the discussion at the workshop, some of the continua were labeled in a way that suggested a spectrum of preference: for example, *Providing Opportunities for Cooperative Learning* was the label attached, and examples that appeared at one end were regarded as poor practice, while those appearing at the other end were preferable.

The project method was but one of many innovations that was rooted in the soil of the "progressive" movement in education. The five essential hallmarks of this long (1876–1957) and influential force that reshape both public and private education were as follows:

- *To see the child at the center of the educational process, with full opportunity for self-expression and the exercise of initiative,*
- *to emphasize learning by doing, including diverse contacts with the real world,*
- *to make the curriculum relevant and meaningful to the learner, with rich materials available for free use,*
- *to make the teacher more of a guide than a "task-master," able to act with self-authority born of solid preparation and professional autonomy,*
- *to make the school a reflection of the contemporary world, and also the home, through close cooperation with parents.*

— R. Ruopp, et al., *LabNet: Toward a Community of Practice, 1993*

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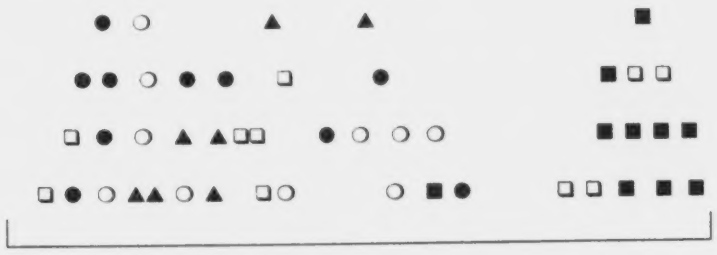
Example from One Workshop

Key:

Mary ○
Paul ●
Simon ■
Eileen ▲
Francis ❑

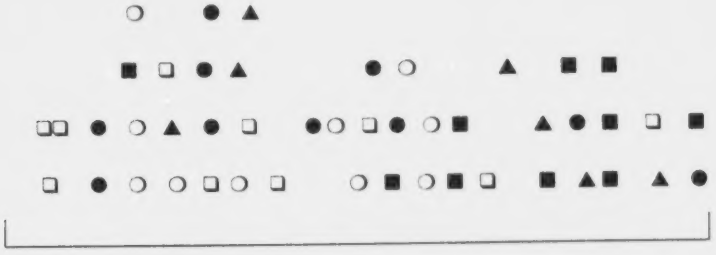
To what extent does the teacher define the activity?

Closely defined — Not defined



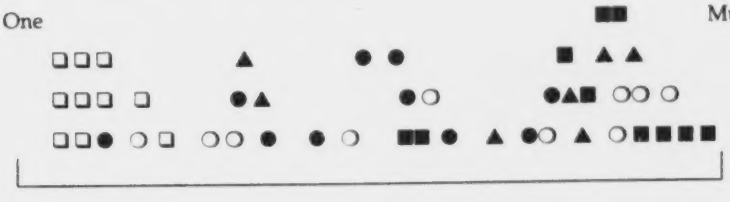
To what extent does the teacher define the methods?

Closely defined — Not defined



To what extent is the teacher expecting one right answer?

One — Multiple



Children need to be fully engaged in order to stretch their learning capacity to its fullest. Motivation is an important part of the learning equation. The task must seem real and important—the stuff of the adult world, not child's play...

Adults learn this way all the time. I have a problem to solve: What do I need to know to solve it? I am meeting a new client next week from the X Corporation, I'd better read their last annual report, and, say, didn't Smith formerly work for X? I'd better talk to him. My company is sending me to France for two years; I'd better learn something about the country, maybe take some language lessons, and what was that about 1992 being a big deal in Europe? I've been assigned to teach physics next year, and I only had three college courses in the subject; better call Jane M., she's been teaching it for years, maybe there's a summer course at the local university; better review the textbook. In each case, the learning is incidental to the presenting task.

— R. Ruopp, et al., *LabNet: Toward A Community of Practice, 1993.*

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Activity Sheet

Reflecting on Practice

To deepen our understanding of project-based science, we have developed an exercise whose aim is to unpack and analyze the underlying issues, in order to help develop a common understanding of what we are talking about. This analysis of the important elements of project-based science we call Reflecting on Practice (R-O-P).

This exercise will form the "backbone" of the workshop: we will carry out an activity and then use the Reflecting On Practice as a framework for discussing that activity.

To begin the process, we will work through an example that provides a framework for looking at the various ways in which science activities are structured in today's classrooms.

On the next page, you will find descriptions by teachers who do project work in science.

Read each description and consider it in terms of three criteria:

- *how precise a definition of the problem is provided by the teacher*
- *how closely the process for working on solving the problem is defined by the teacher, and*
- *how open are the problems, i.e., how many solutions are possible.*

On the following page, you will find a sheet with three continua to help you structure your reflection. Decide where you would place the activity on each continuum and record the description name. There are no right or wrong answers; these are meant to provide a primer for discussion.

You may feel that a specific teacher's description does not provide sufficient information, in which case you may make an assumption or simply not code that description.

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Activity Sheet

Teacher Descriptions

Description 1: Mary

In their science work, I like to give my students the opportunity to select projects they find interesting within a particular topic. The main thing is building an interest in science. For example, while we were working through our human physiology unit, I prepared descriptions of possible experiments for my students to choose from. Halfway through the projects, we met as a class to discuss the range of discoveries they had made. I want to give them an opportunity to follow their own interests and to have some choice in what they learn because it is only when students are interested that they will really learn something.

Description 2: Paul

In my science class, I want my students to learn to think about what they are doing and why they are doing it. I start my class with a question; for example, do all seeds germinate in the same way? I allow plenty of time for class discussion for students to identify the factors involved, the controls needed and so on, before they do the experiment. Discussions are important, because it is only when you hear students talk about what they are doing that you can tell whether they have really grasped the content. So that is why, after the experiment is completed, we end the class with a discussion.

Description 3: Simon

In my opinion, the important thing is the approach. Each semester, I have my students choose a science topic of interest to them. Each group plans an initial experiment and then I check their plan to make sure they are all safe and doable. After carrying out their initial exploration, students design a second one based on questions emerging from the first. You see, I don't really care whether my students learn the details of any content area. What I am most interested in is their learning science process skills and learning to work cooperatively in groups.

Description 4: Eileen

I am interested in having my students understand science as a social endeavor. For example, last month I presented my class with the question: *Does a car heat up more in the summer or the winter?* They were instructed to discuss their ideas with members of their group. Groups then met for an all-class discussion and shared ideas. Together they generated a list of factors that might affect how much the car heats up. Each group chose one factor from the list to investigate. After testing their factors, the group shared their investigation designs and results. Then each group used the combined findings of all groups to design a prototype (on paper) for the best Heatkeeper.

Description 5: Francis

Project work is all about students being in charge and designing their own experiments. For example, the students develop questions related to our topic of study. They spend the next week exploring their questions. They come up with an initial plan for their chosen question, and present that plan to the class. The class votes on the best plan, and together we revise it. Only then, when the plan is agreed upon by all, when everyone is happy with the plan, only then do I work out an experiment that will answer the chosen question, and the students then carry it out. At the end of the experiment, we share results to make sure that everyone has arrived at the solution.

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Continua

To what extent does the teacher

define the activity?

Closely defined — Not defined

To what extent does the teacher define the methods?

Closely defined — Not defined

To what extent is the teacher expecting one right answer?

One — Multiple

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Continua

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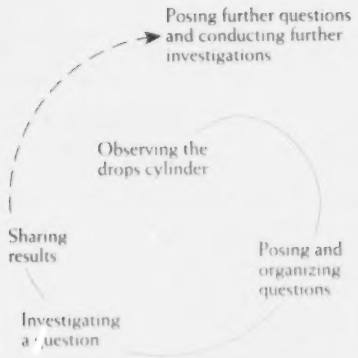
Overview

Watching The Drops


Posing further questions and conducting further investigations
Observing the drops cylinder
Posing and organizing questions
Investigating a question
Sharing results

Materials

Drops cylinders, one for each teacher to take away*

Stopwatch

Handcounter

Containers

Water

Vinegar

Vegetable oils

Kerosene

Food coloring

Other drops models that involve a similar process (optional)

Paper towels

Eye droppers

* If drops cylinders are not available or within your budget, substitute the activity Drops on a Penny, which provokes the same kind of questioning about liquids and grappling with data.

Resource Material

Page A-1

Purpose and Rationale

This activity is designed to give teachers a first-hand experience doing science in the constructivist spirit. This means they need to remove themselves from the role of "teacher" and become "learners." This activity with the drops cylinder was chosen as one sufficiently different from usual classroom work in order to make it easier for teachers to adopt the learner role. While many may have seen objects like the drops cylinder, few will have explored the science behind how it works.

An important part of learning is attention to process. In this activity, the science process skills that teachers use include

- **posing questions,**
- **organizing questions into different categories,**
- **conducting investigations to find answers,**
- **communicating observations and results, and**
- **posing further questions and conducting further investigations.**

Synopsis

There are three stages to the Drops activity, plus an optional fourth stage:

In the *Opening Activity*, teachers work in groups to generate questions. Then the whole group comes together to share questions and organize them into categories.

In the *Exploration*, working in small groups, teachers conduct experiments to find answers to some of their collected questions. Then the whole group comes together to share the results of their investigations.

In the *Synthesis*, lead a discussion on "Where is the science in all this?" Then do the *Reflecting on Practice on the Drops Cylinder*. Time: One-half day.

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Watching The Drops

Opening Activity

Asking our own questions is something we all tend to believe in. Yet little in any of our various educations is likely to have emphasized this.

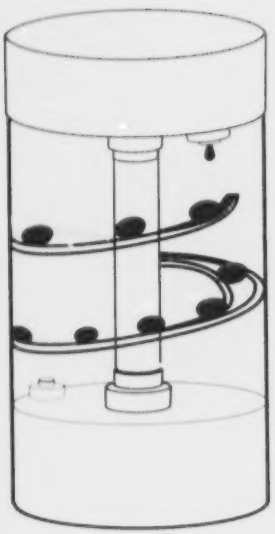
Present teachers with the drops cylinders, maybe groups of five or six teachers together. Ask them, *What questions do you have as a result of watching this?*

After groups generate lists, bring everyone together to share questions from the different groups.

In one workshop, the number of questions that were generated was overwhelming, and some teachers suggested setting up categories as a way of organizing the list.

Here are the categories they came up with:

- *drop rate/speed questions*
- *construction of the drops cylinder questions*
- *drop behavior questions*
- *investigations questions*



Questions Asked by Teachers

What are the liquids or materials inside?

Why does the size of the drops change?

What are the intervals between drops?

What is under the white top?

The blue liquid comes from the same hole as the air, why doesn't it come out of the space it entered?

Exploration

Divide participants into small groups again and ask each group to add new questions and refine their list of questions by categories. Invite each group to address one or more of these questions through an investigation. Call attention to the materials available for their use. As groups develop their investigations, have them keep notes on

- *what your goals are,*
- *what you think you might find,*
- *where you think problems might arise, and*
- *what your main findings are.*

Each group then shares its findings with other groups. This step could take several forms. For example, a pair of project teams interchange half their members, and the hybrid teams each analyze both team projects. This places the burden on each member of each team to

- *be the "intelligent outsider" asking good questions about the project they were not part of,*
- *be the clear communicator of the project they did to those who did not participate.*

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Synthesis

Follow the group sharing with a discussion about "Where is the science in all this?" Help the participants to focus on their own learnings and understandings that developed through this activity.

Extensions

Initial investigations often trigger further questions that suggest further investigations, as described in the following story:

Where is the Science?

Workshop participants were asked to contribute answers to the question, "Where is the science?" Their initial answers to this question were all about science process, and it was only after pointing this out that people also contributed science content responses.

Science Process:

- Experimental design: variables and controls
- Compare/contrast: observation, quantitative vs. qualitative
- Communication
- Hypothesizing
- Recording data
- Evaluating results and making conclusions
- Cooperative learning strategies
- Problem solving

Science Content:

- Density: floating and sinking
- Properties of liquids: viscosity, surface tension, miscibility
- Head pressure
- Water clocks
- Archimedes thermometer
- Specific gravity
- Gravity
- Fluids in zero gravity

until he (the child) has a great deal of data, he has no idea what questions to ask, or what questions there are to ask.

J. Holt,
How Children Learn, 1971

Reflections of a Workshop Leader

One workshop group asked to have alcohol as one of the liquids to test. Experiments with colored alcohol dropped onto both water and vegetable oil quickly demonstrated that alcohol was not one of the liquids in the drops cylinders. However, the alcohol drops were interesting in their own right, and a new exploration was born.

The exploration was interesting but the phenomenon was complex. After a series of experiments, I said to the group:

> *The questions this raised far exceeded our capabilities to answer. We were fascinated, we were thrilled, we loved watching the patterns, but the interactions seemed much too complex to be understood and explained. Is this a bad activity to use in a workshop since it raised so many questions we could not answer?*

Their answer was an emphatic No! "You don't need to always have the answer," they explained. "Sometimes it is enough to just marvel."

That was not the answer I expected. On the other hand, it was marvelous to hear. Everything does not need to be nailed down. "Sometimes it is enough to just marvel."

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Reflecting On Practice

Opening Activity

Having just completed an investigation, invite the participants to reflect on its structure by performing an R-O-P analysis on the activity.

Hand out to each participant one sheet containing the labelled continua and the other containing unlabelled continua.

Now that each participant has worked through the original R-O-P activity, and has carried out the *Watching the Drops* activity, we want to give each person a chance to develop his or her own synthesis before sharing with others.

Have the participants, working alone, consider the whole range of *Watching the Drops* activities they have just completed with respect to the prescribed labels that concern teacher versus student control. In addition, invite participants to invent their own labels for the continua on the second sheet to extend the analysis of the *Watching the Drops* activity.

Exploration

Group participants into small groups of 3 or 4 to share their assessments of the *Watching the Drops* activity and to discuss differences among them.

Synthesis

Encourage participants to suggest recommendations for presenting the *Watching the Drops* activity in a different way so as to capture some of the desirable features they have identified. This forces the question: What is desirable?

A written report from each participant about what he or she learned about the nature of project work, in a journal or to be shared with the whole group, could be useful as a way to round off this activity.

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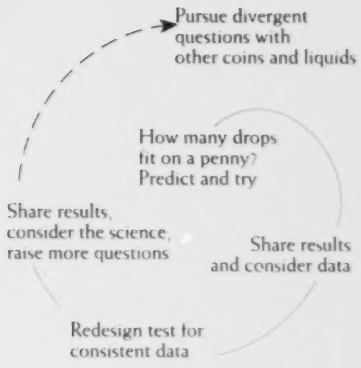
Overview

Drops on a Penny


Pursue divergent questions with other coins and liquids
How many drops fit on a penny? Predict and try
Share results and consider data
Redesign test for consistent data
Share results, consider the science, raise more questions

Materials

Pennies

Plastic droppers

Small cups for water

Petri dishes or plates to contain the spill

Water supply

For further investigations:

Rubbing alcohol

Liquid dishwashing soap

Materials to coat coins such as Vaseline or vegetable oil

Assortment of coins of different sizes and materials

Resource Material

Page A-2

Purpose and Rationale

This activity accomplishes the same purpose as *Watching the Drops* with a less-expensive set of materials. While teachers may have done *Drops on a Penny* before, they will not have been likely to explore the problem or the questions it raises about data to the depth we suggest here.

Synopsis

Participants encounter a phenomenon that at first seems simple, but that provokes many questions and avenues for exploration. They come together to discuss their initial explorations and to try to make sense of the messy data. They then reflect on how to redesign the investigation to get more consistent data and consider: Where is the science?

In an extension, participants may pursue divergent questions that arose out of the initial activity — using other coins or liquids. Time: One-half day.

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Drops on a Penny

Opening Activity

How many drops will fit on a penny?

First, predict how many drops you can put on a penny; then try it.

Exploration

Share results of the initial predictions and trials and then do more trials, collect more data, try some variations, with the idea of coming back together in about fifteen minutes to share observations and questions.

The issue of scattered data is particularly applicable to this activity. Again break up into small groups and try to deal with this problem and come up with a more consistent set of data.

Synthesis

Have a discussion with the group on: Where is the science in this activity?

Extension

Once procedures have been standardized and the remaining degree of scatter recognized, the effects of other variables can be investigated, such as trying different materials. In addition to comparing numbers of drops, notice differences in the behavior of the drops and the pile of drops. For instance, using soapy water, is the drop size the same? Is the shape of the pile similar? How does the way the liquid spills off the coin compare from one trial to another when the last drop is added? Together participants may consider what they can conclude about the three forces: gravity, cohesion and adhesion, based on their observations.

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Questions that emerge, some after further investigations:

Heads versus tails: what is the difference in the number of drops?

How do you deal with the spread of data?

Are drop sizes uniform: from drop to drop and dropper to dropper?

What is the effect on drop size of the angle at which the dropper is held and the pressure used when squeezing the dropper?

Is the surface of the coin different on successive trials in ways that affect the result? For instance, using a coin that has been cleaned off after an earlier trial when the coin was coated with Vaseline.

What if you try other liquids, such as alcohol, vegetable oil and even corn syrup?

What is the relation between coin size and number of drops?

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Overview

Introduction to MBL

Introduction to Activities

The following set of activities are designed to introduce participants to microcomputer-based laboratories (MBL) through their own learning and also to raise and address various issues related to using MBL to support elementary science learning in the classroom. The activities *Cold Hands/Warm Heart?, Representing Change, Cooling Works, Investigating Motion* and *How Does Light Behave* each explore aspects of science content and process using the technology and leave participants with a set of questions that they may pursue in the *Project Work* activity. We chose to focus the project on change to highlight one of the more powerful features of MBL — the ability to record and graph changes in data over very long or very slow time periods—data that would otherwise be too tedious for elementary children to collect and analyze.

The activities *Cold Hands/Warm Heart?, Cooling Works* and *Representing Change: A Melting Popsicle* all address various aspects of heat energy and heat transfer using the MBL temperature probes and software. We have chosen to focus on one probe and related science to allow participants extended and deepening experiences in the same content area. *Exploring Motion and How Does Light Behave* each introduce an additional probe.

Notes for Implementing MBL in a Workshop Setting

The *Resource Material on MBL* in the back of this manual is designed to give both you and your teachers a general overview of the technology and its application to elementary science learning. We also provide information on additional probes, vendors and costs. The following information relates specifically to planning, setting up and running a teacher workshop.

Resource Material

Page A-21-23

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Introducing MBL in a Workshop Setting

Many elementary teachers who have computers have experienced using the word processor in whole-language work to facilitate the process of writing and editing. In many ways, the MBL is analogous to the word processor. In science, the emphasis is on making observations and carrying out investigations. The MBL facilitates the process of gathering and representing data. This provides more opportunity for learners to pay attention to the data—to interpret it, redisplay it and analyze it— to inform their understanding of the phenomenon. Since the time span between changing a variable in their investigation and seeing the results is shortened, learners can ask more "what if" questions and are more likely to revise their test design and try it again.

The MBL also introduces learners to two standard representations of science data: bar graphs for discrete data and line graphs for continuous data (data that changes over time). Learners acquire the "language" of graphing in the process of using the MBL to further their own understandings. Prior to their experiences with MBL, learners are provided opportunity to create their own representations of data, for there are many more ways to "see" patterns and express understandings than those used by the computer.

Most elementary teachers will be new to MBL technology and need an intensive amount of time to explore the technology in the context of their own learning. Rather than try to teach the specifics of any one product, we have designed the MBL workshop activities to get teachers using the tool in the context of science learning. Once they understand the potential of MBL, teachers can choose which probes and software packages might best support their students.

When Setting Up MBL Stations for the Workshop

- *You will need sufficient access to technology for all participants. We recommend at least one completely equipped computer station for every three to four participants.*
- *It is a known fact that the likelihood that the technology will fail is directly proportional to the number of people watching you demonstrate it. Set up and test all MBL stations completely before demonstrating the software to participants. This includes cable hookups, software settings, printers, probes and calibration.*
- *It also helps to have spare parts of all kinds available — probes, cables, even a computer if possible.*

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When Introducing MBL in the Workshop

- *Provide participants with a simple, one-page "crib sheet" for the typical functions your participants will use in the software. Limit the information to only those features they will need for the investigation.*
- *Model use of the software, demonstrating that it is easy to use. Particularly if participants are new to MBL and to the software, show them only the functions they will need for the activity, specifically, how to collect, save and print their data.*
- *Consider using an overhead projection screen for your computer when demonstrating the MBL. You may also benefit from an overhead when it comes time to examine participants' graphs. We have found that printing line graphs out on acetate and using an overhead to compare several at one time helps participants "see" differences and compare results from several tests. Remember to keep the scale of the axes on all printouts the same for this to work.*

Facilitating an MBL Workshop Activity

As workshop leader you will find yourself caught between answering technical questions and helping the participants use the MBL to explore science phenomena. We have designed the activities to lead from very simple to gradually more complex applications of MBL and the software, with the expectation that participants will focus on the science and not just the tool itself. As leader, set an atmosphere of "try it and see what it does" and limit your technical explanations to brief demonstrations and "crib sheet" handouts that guide users through the software. Remember that the participants have a unique opportunity in these workshops to explore their own ideas and pursue their own learning about science. You can always get in touch with someone after the workshop to provide additional technical information.

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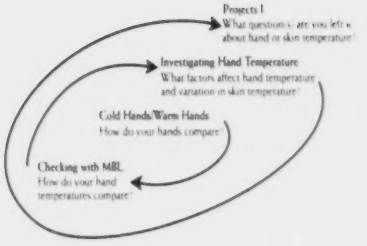
Overview

Cold Hands/ Warm Heart?


Projects I
What question(s) are you left with about hand or skin temperature?
Investigating Hand Temperature
What factors affect hand temperature and variation in skin temperature?
Cold Hands/Warm Hands
How do your hands compare?
Checking with MBL
How do your hand temperatures compare?

Materials

- Computers and probes for each group of 3 to 4 participants.
- Instructions for how to get started at each computer
- Prepared chart for recording hand temperature
- Post-Its
- Large paper
- Markers
- Various cotton, synthetic and wool socks
- Mittens and gloves
- Plastic baggies, paper bags, etc.
- Source of cold and heat — water faucets and/or ice
- Box of crackers, chocolate bars
- Cassette player with soothing and raucous tapes
- Cups, containers
- Additional materials as requested by participants and as available

Preparation

Test each computer setup a day or two before the workshop. Have extra probes available.

If this is the participants' first experience with the MBL, you may want to have the computers started and the probes calibrated before the workshop.

Purpose and Rationale

The purpose of this set of activities is twofold. First, the activities introduce the workshop participants to the microcomputer-based lab within the context of a learning experience and second, they provide a complete example of how project work grows from instructor-initiated experiences toward those in which more responsibility for decision making shifts to the learner.

The opening experience helps the participants focus their attention on hand temperature and consider their own ideas about the phenomena. The activity begins with a sense-of-touch exercise so that participants will continue to rely on their own senses for data as well as the tool.

This is the only example in the leader's manual in which we model the full process of initiating work with a topic and then carry it directly into self-initiated project work. Two more projects are described in the manual, but they are based on experiences with several topics.

Synopsis

In the Opening Activity, *Cold Hands/Warm Hands*, participants use their sense of touch to arrange themselves according to increasing hand temperature. They then confirm or negate their original ideas about this order by using the MBL temperature probe to obtain temperature data. Time: One and one-half hours.

This leads to the next activity, *Investigating Hand Temperature*, where participants choose and investigate a factor that they think might affect hand temperature. Time: Three hours.

The set of activities culminates with *Human Physiology Projects* where the participants identify their own question to investigate, plan a strategy for investigating the question and carry out their plan. Time: 5–10 hours, spread over two days.

Resource Material

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Cold Hands/Warm Heart

Opening Activity

Whose hands are warmer?

Ask participants to think about the temperature of their own hands. Then invite them to compare hand temperatures with the person next to them and to consider whose hands are warmer and what the temperature difference is. This will heighten curiosity and spark questions about the variation in hand temperature.

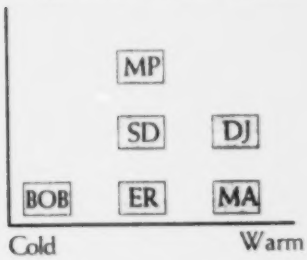
Next, challenge the workshop participants to line up in order of increasing hand temperature. While it may take a minute or two to identify a strategy, once started, the ordering will occur quickly.

When the participants have established an order, ask the individuals at each end of the line to feel each others' hands and predict the difference in temperature (in degrees Celsius.)

Participants note their positions in the line starting from the left end (e.g., first, second, third) and record their positions in order by placing their names on a prepared chart.

This nonMBL experience will help set the context for understanding what the MBL does and how it enhances learning.

Temperature of our Hands



Exploration

What is the actual temperature of your hand?

Explain that the MBL can be used to check their hand temperature order. First demonstrate how the probe works, sharing the basic information needed to begin using the technology. (See gray box on the next page.)

Then, in groups of three or four, have the participants gather data and make a printout of individual hand temperatures.

In your interactions with each group, emphasize the phenomenon by asking questions about variation in hand temperatures among members of the group. Emphasize data gathering procedures by asking the participants to describe how the data is being gathered. For example, are all placing the probe on the same part of their hand?

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Introducing the Microcomputer-Based Lab

We have found modeling to be an effective strategy. While participants may not remember all the steps, they should feel that the technology is not difficult to use. Provide the participants with a simple "crib sheet" to help them. During the introduction identify and explain:

1) *parts of the MBL*
2) *parts of the MBL/computer hookup*
3) *how to use the software, hardware and probe together*
4) *the appropriate way to use the temperature probe, e.g., the importance of touching the object with the exposed metal tip of the probe and the need to provide sufficient time for the probe to stabilize*
5) *how to print*

The central goal of the workshop is to become familiar with ways that the technology can support science learning. While participants will learn much about the tool, they will not become experts. The emphasis is on learning about the phenomena with the support of technology, not how the technology works — this is a delicate balance.

Synthesis

Once all individuals have data about their hand temperatures, bring the groups together. Encourage the participants to come up with a strategy for organizing and representing the collective MBL data so that this data can be compared to the earlier gathered sense-of-touch data.

Once the data have been organized, compare findings with the earlier predictions and consider the implications. This discussion provides a bridge between thinking about temperature variation among people and thinking about variation for an individual. During the discussion some of the following questions might be addressed:

How does this order compare to your "sense-of-touch" predictions?

What might cause differences between the two orders?

What is the range of hand temperatures?

Is the difference between the warmest and coolest hand what you expected?

If you did this at a different time or under different circumstances, how might the data be different?

If you found the temperature of just your own hand at different times or under different circumstances, what kind of range might you expect?

Workshop Experience

During a summer workshop, participants lined up in order of printouts and noted some differences between that lineup and the original order. Their discussion included reliability of the data and calibration of probes, as well as how hand temperature might have changed during the data gathering period.

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Investigating Hand Temperature

Exploration

What factors cause variation in your own skin temperature?

During the opening activity, participants compared their own hand temperature to that of others. In this experience, they are asked to consider factors that might cause the temperature of their skin to vary. Participants may choose to consider why there is variation with change of treatment, e.g., hand temperature with different kinds of gloves, or variation from one skin location to another, e.g., palm of hand, fingers, nose.

Invite the participants to identify and test one factor that they think might cause the temperature of their own skin to vary. The following guidelines may be helpful:

- *Brainstorm possible factors (both internal and external) that might influence skin temperature.*
- *Choose one factor to investigate.*
- *Devise, refine and carry out an investigation to test the factor. Consider not only to how much the temperature changes, but how it changes.*
- *Be prepared to report your investigation findings to the other groups.*

Allow approximately two hours for brainstorming, choosing a question and investigating. Encourage each group to consider everyone's ideas and then agree on one question/factor to investigate. A table of optional materials (e.g., socks, plastic bags, gloves, mittens, box of crackers, cassette player, hats, ice) can help generate ideas as well as establish parameters for the investigations.

Groups should carry out their investigations and at the same time become more familiar with the technology. Remind the participants that all should have an opportunity to work with the MBL.

Your role will be that of facilitator — provide supplies, clarify directions, encourage alternative ideas, focus investigation strategies and provide technical help.

Participant Questions from One Workshop

Is the temperature uniform across your palm?

Does gender make a difference?

What relationship does hand temperature have to circulation?

How do hand and foot temperature compare?

Does age make a difference?

Are the palm and the back-of-the-hand the same temperature?

Could you develop an index to look at variables of one's hand such as fat content and/or size?

Are the temperatures of all your fingers the same?

Is your right hand the same as your left?

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Synthesis

Following the investigations, bring everyone together. Suggest that participants share

- *what their group investigated,*
- *how they structured their investigation,*
- *what they found out, and*
- *new questions they have.*

Listen for and highlight any teaching themes that arise during the discussion, e.g., the collaborative work experienced by participants may serve as a springboard for discussing the role of collaboration and communication in science learning.

Where's the science? Once the groups have shared their investigations, consider the science learnings that emerged. The learnings may be different from what participants are accustomed to thinking about as relevant science. It is important to emphasize that the learner does not come away from the activity with a list of facts about the human body, but instead awareness, questions and connections grounded in direct experience.

Discussion questions might include:

What are your understandings about skin temperature? Have your understandings changed?

What is the value of this kind of learning?

Did MBL support and extend your learning or did it get in the way?

What new questions have your investigations raised?

Collate participants' understandings and questions on chart paper.

Workshop Participants' Comments about How MBL Supports and Extends Learning

Probes opened possibilities for investigations.

Immediate feedback provided by the MBL spurs further curiosity.

MBL probes "extended" the senses.

Instrumentation made for efficiency in the investigation.

Being able to gather, represent and analyze the data so quickly was good.

MBLs allowed us to see real data represented in graphs.

MBLs compressed time so we could focus on cause and effect.

Beliefs about Hand Temperature

In a summer workshop, participants were asked what they knew about hand temperature both before and after their investigation. These were their responses:

Before Investigating:	**After Investigating:**
Not the same as core temperature.	External factors can cause a change.
Different for different people.	Hand temperature varies with each individual.
Higher if you close your hand.	Changes happen in short periods of time.
May relate to emotions.	Generated "what-if" questions.
Related to activity level — exercise or using your hands.	More things affect hand temperature than I had originally thought.
	We know more about what we don't know.

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Human Physiology Projects

Exploration

Participants are invited to continue their work with skin temperature and refine their earlier investigations, or to try another group's ideas. Alternatively, they may choose to consider other functions of the human body such as breathing rate or pulse. The experience with skin temperature provides a model for studying other functions, that is, first explore the phenomenon and then investigate factors that cause variation.

It is important that the participants stay with their own learning and not shift to implications for the classroom at this time. The intent is for them to experience project work in their own learning.

What questions have emerged as a result of our explorations? Where will you go next with your investigations? Are there others who are interested in pursuing the same issues as you?

Begin with the list of questions generated during the last activity. Have the participants consider a focus for their project work. Suggest that groups of three to six participants work on questions of interest. Set expected time frames and checkpoints.

Identifying a question to investigate: It is important that the participants' questions are their own. Shaping the question so that it is investigable is an important part of the scientific process. A group beginning with the question "How will exercise affect hand temperature?" might modify their question to "How does hand temperature change after two minutes of running in place?"

Planning the investigation: Encourage participants to consider what data will help answer their question and how that data might be gathered.

What evidence will you look for?

How will you gather these data?

Would it be useful to compare data from two or more sources? under different circumstances? or at different times?

How will the MBL probe(s) and software help you to gather and represent your data?

Conducting quick trials: By conducting quick trials and revising their plans, the participants experience the "debugging" involved in doing investigative work.

Questions Workshop Participants Investigated

How will exercise affect hand temperature?

How are pulse rate and hand temperature connected?

How does relaxation or stress affect hand temperature?

What parts of your hand are the warmest?

How does ambient temperature affect hand temperature?

Does eating chocolate affect hand temperature?

Does holding your hand at your side and holding your hand above your head affect hand temperature?

Does it matter whether your gloves are wool or cotton?

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Does the data you collected help answer your question?

Did you find patterns that might suggest additional questions?

What changes do you want to make in your question or investigation strategies to improve your research?

Peer review: Have each project group meet briefly with another group to review their investigation plans and progress. During this peer review, encourage the groups to share

- *the original question,*
- *the quick trials — what was done and what was found, and*
- *revised question and research strategy.*

Sharing investigations with others outside the group provides opportunity for seeing alternatives and clarifying plans.

Gather, organize and analyze data: Have the participants gather data according to their investigation plans. Representing data in multiple ways can help them to note different aspects of the data. Encourage the participants to make their own representations, as well as using the computer-generated graphs.

"Publishing" the results: Set aside time for groups to decide how to share their findings and work in progress with the other groups. The following questions may serve as guidelines for this planning:

How did you organize and represent your data? What patterns and/or trends did you find?

What conclusions can you make from your evidence? Does the evidence you gathered answer your question?

How do your findings contribute to your understanding of the phenomena?

What learning was involved in your experience with project work?

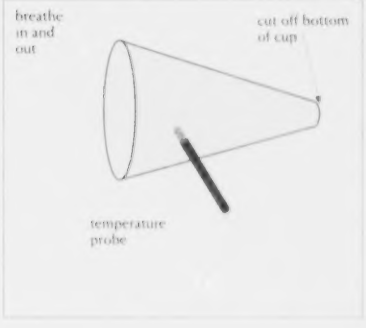
How did the MBL influence your learning?

During the presentations encourage the participants to communicate directly with each other. Your intervention should focus the discussion on relevant issues and help set a reflective tone.

Making findings and procedures public is part of science. Encourage the participants to think of their work as "research in progress" and to welcome critique as the first step in designing the next phase of their research.

Breathing Rate

The MBL temperature probe can be used to gather data about breathing rate by measuring the temperature of the air exhaled and then inhaled over a set period of time. One strategy is to place the temperature probe through a hole in the side of a cone-shaped paper cup with the end of the cup cut open for air to escape, and then hold the cup up to your mouth while breathing.



Pulse Rate

While pulse rate data can be gathered without the MBL, there are probes that will do this for the learner. The pulse probe is most often a small light probe that attaches to the ear lobe and measures the amount of light that passes through the lobe. The pulsing of blood in the lobe causes variation in light level and thus provides data about pulse rate.

Participant Quote

We worked hard all morning at planning and setting up our investigation. At noon we still had no data. If this had happened in my classroom, I would have accused the students of being off track.

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Synthesis

In groups of three to six, participants reflect on their experience to clarify their understanding of what project work is. Encourage them to work with people from the other project groups so that they hear about experiences different from their own.

How was this experience similar to the work of scientists?

How would you describe project work to someone else?

Have your understandings of project work changed?

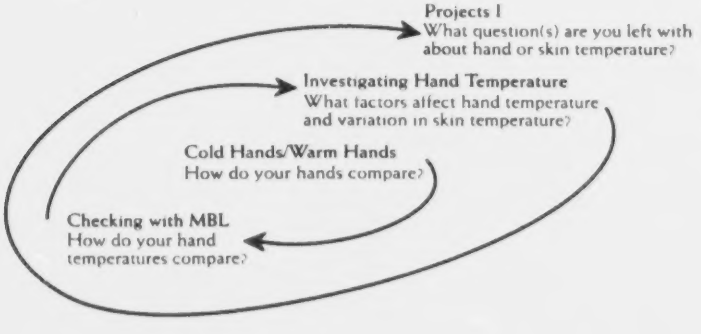
Invite each group to represent their ideas about project work on a large sheet of chart paper. Provide time for each group to share their representation. As part of each presentation, encourage the presenters to share questions and issues that they have about doing and supporting project work.

Parts of a Scientific Research Project

How do scientists do science? Is there a sequence to their work? We may think of an investigation as progressing in an ordered manner, but in reality, the process often starts by "messing around" with a phenomena and asking quick "what if" questions.

As teachers do science, they experience the cyclical nature of science and employ skills that scientists use in their work. Their experience with project work supports an understanding of the nature of science by including time for "messing around" and ongoing revision during the process of testing ideas.

Scientific Process: One Model


Projects I
What question(s) are you left with about hand or skin temperature?
Investigating Hand Temperature
What factors affect hand temperature and variation in skin temperature?
Cold Hands/Warm Hands
How do your hands compare?
Checking with MBL
How do your hand temperatures compare?

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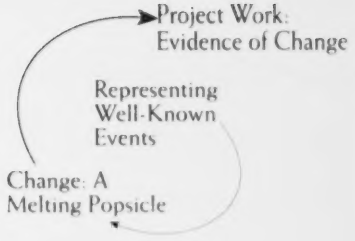
Overview

Representing Change



Purpose and Rationale

One of the strengths of the MBL is its ability to gather and represent data about change. This section focuses on representations of change over time. Participants explore various ways of representing change and interpreting representations created by others. These experiences help ground and extend participants' understandings of data representation before continuing work with the MBL.

Change is one of six central themes identified in *Science for All Americans*. The activities in this section are meant to help the participants think overtly about this theme and how information about change is represented. Participants consider the changes that occur in an event and then create their own representations of those changes. The intent is to be able to see multiple ways of representing change and to recognize the importance of symbolic information in representations.

Synopsis

In *Representing Well-Known Events*, participants first create and share their own representations of well-known phenomena (such as, change in the amount of light in the classroom over a 24-hour period). Time: One and one-half hours. Then, in the second activity, *Change: A Melting Popsicle*, they are then asked to represent the melting of a Popsicle. Time: Two – three hours.

Materials

- Chart paper
- Marking pens
- Popsicles (4 for each group of 2 to 3 people)
- Hair dryers or other source of heat to speed up melting
- Graduated cylinders and other containers for measuring volume
- Spring scales
- Plastic cups
- Paper towels

Preparation

Write the list of everyday phenomena (on the following page) on chart paper so that all participants can see.

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Patterns of change are of special interest in the sciences: Descriptions of change are important for predicting what will happen, analysis of change is essential for understanding what is going on, as well as for predicting what will happen, and control of change is essential for the design of technological systems. We can distinguish three general categories: (1) changes that are steady trends, (2) changes that occur in cycles, and (3) changes that are irregular. A system may have all three kinds of change occurring together.

— *Rutherford and Ahlgren*

Science for All Americans, 1990

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Representing Well-Known Events

Opening Activity

How do representations help us to communicate information about phenomena?

The activity begins with a discussion about representations. You might begin with pictures and art as representations of phenomena and feelings. The word "graph" is purposely avoided in introducing the activity to allow for consideration of multiple and nonconventional representations.

Share the following or a similar list of common phenomena and ask the participants, *How would you represent one of these phenomena on paper?*

Everyday Phenomena Involving Change Over Time

Coffee consumption (e.g., in the student union of a university, or in a faculty room or in this state, etc.)
Number of people in a school faculty room
Noise level in a 4th grade classroom
Light level in a 4th grade classroom
TV watching (e.g. in this town, households in this group, or 4th graders in this state, etc.)
Number of cars going into the city
Other?

Choosing Everyday Phenomena For This Activity

Ideally, each phenomenon should be something familiar and broadly defined, with the possibility of an interesting story attached. The activity is made richer when different representations are possible and there are multiple variables for people to consider. Each should be a phenomenon that changes with time.

Exploration

Participants work in groups of three or four. Each group chooses one phenomenon from the list and creates a representation. Deciding how to represent the phenomenon and over how much time to represent it is the participants' task. Instruct the participants to communicate information as clearly as possible, but without using labels on their representations. Provide each group with a large sheet of chart paper and markers for the activity.

When groups have completed their representations, display and discuss each separately. The discussion about each representation might begin with the observations, questions and, finally, guesses about what is represented. Then provide time for the group members to tell their own story of what is happening in their representation. The purpose of the group sharings is to recognize the variety of ways that events can be represented, to increase awareness of the kind of information in representations and to provide a forum for interpreting representations.

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Participants may use informal vocabulary to describe change over time. For example, a participant might say, "It starts off by staying the same for awhile, then it gets less pretty fast, then it gets steady and doesn't get much less."

This kind of informal description is important. The introduction of words such as rate, speed and acceleration can come later.

Science for All Americans identifies three categories of change: 1) changes that are steady trends, 2) changes that occur in cycles, and 3) changes that are irregular. You may want to ask participants which category or categories the phenomena they represented fall into.

Drawings, like words, have meaning — often beyond the power of words to express, but nonetheless invaluable in making the chaos of our sensory impressions comprehensible.

— Betty Edwards,
Drawing on the Artist Within: A guide to innovation, invention, imagination and creativity, 1986

Synthesis

Provide opportunity for the participants to reflect on their own learning.

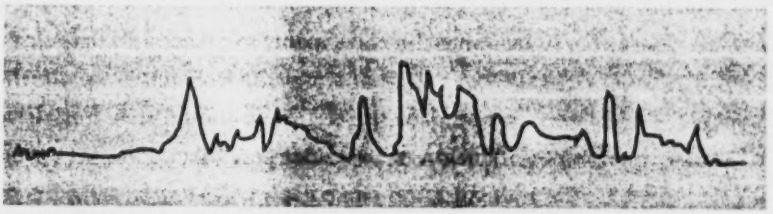
What kinds of things did you learn about the specific phenomena as you created your own representations and interpreted others' representations?

What implications does this activity have for work with graphic representations on computers?

Representing Change

At first, the teachers seemed puzzled by how they might create their representations, but they quickly broke into pairs and started discussing which phenomenon to choose and how to represent it. They compared previous experiences and discussed what they thought might happen.

Martha and Ann chose to represent noise level in a 4th grade classroom. First, they agreed that they would represent a cooperative learning classroom so that it was "Okay for it to be noisy." They talked about their typical day, weaving an intricate story of what was happening in the classroom. Because they wanted their representation to be true to their story, their representation was very detailed, including "little blips" that represent the gerbil wheel turning when there is no other sound in the room.



When Martha and Ann presented their representation, others noted the detail and quickly guessed that it must be about noise.

A lively discussion about shape and trends in the data followed. Knowing that the line was noise level and having experience with fourth grade classrooms, other teachers easily followed the line guessing what might be happening at each peak and valley. Knowing the context of the data meant a richer discussion about the representation.

Ann noted that showing sudden changes was a challenge. She wanted to draw the line straight up but knew that the line needed some "slant." She noted that even quick change is not instantaneous and she wanted to show that with the line.

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Synthesis

Invite one participant from each group to meet in one of several small groups (for approximately 20 minutes) to consider ideas and questions raised during their experience with the melting Popsicles. The focus of the small group discussions should be data gathering, data representation and data analysis strategies.

During the presentations encourage individuals to compare test design and findings. *Are your group's strategies and findings the same as another group's?*

A whole-group session might follow to bring ideas together about change. Consider whether the melting of a Popsicle is a steady trend or cyclical or irregular change based on the data gathered.

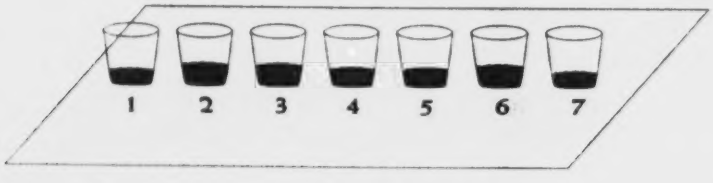
Did Popsicles melt at a steady rate in all the tests? In any of the tests?

How has your understanding of melting changed?

A Workshop Experience: A Melting Popsicle

One group of teachers in an after-school session decided to measure melting by collecting drips in small plastic cups, changing cups each minute. They speeded the melting process with a hair dryer.

Quantifying Popsicles



They then lined up their cups and observed the following:

L: I would say that it starts slower, then it increases. It goes faster, and we saw it happening. Once that melting action started, there was a peak point. There's something that happens once the melting starts...and then, I don't know — the adjustment of these or the temperature and the pressure or whatever didn't really begin to influence it at a point, and at 5 it changed again. And in 7 is the end result —

D: ...and the dripping process was slow. But when it's smaller, it beats me why it would go slower.

L: What is it that makes it different, I wonder...why doesn't it change consistently?

Note

Two visually rich and helpful reference books about ways to represent phenomena are *The Visual Display of Quantitative Information* and *Envisioning Information* both by Edward R. Tufte, a professor of Political Science and Statistics. Publisher: Graphics Press, Box 430, Cheshire, Conn. 06410. These could be very useful to you and to teachers as they reflect on what representations communicate about data.

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Change: A Melting Popsicle

Opening Activity

While different groups focused on different phenomena in the last activity, they will now observe and represent the same everyday phenomenon, the melting of a Popsicle.

Pose the question: *How might you represent the melting of a Popsicle?*

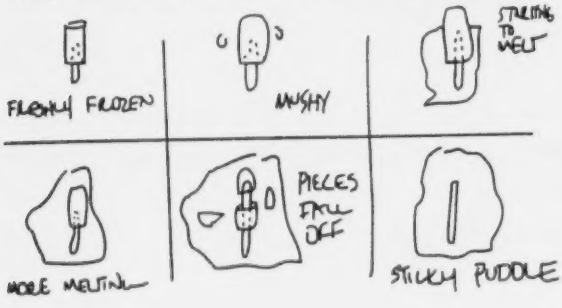
Have the participants work in groups of three or four for approximately 10 minutes to create their own representations of what they predict will happen when a Popsicle melts. Then display the representations in a common area and ask groups to explain their representations. Following the presentations, ask the participants:

What do some of the representations tell you that others do not?

Can you compare these various representations? For instance, is "half gone" on one comparable to "half gone" on another?

If you were conducting research on melting Popsicles and wanted to compare data, how might you "quantify" this phenomenon?

Representation of a Melting Popsicle



Exploration

Challenge the participants to devise a strategy for gathering data about change over time of a melting Popsicle. Explain that we want to be able to compare the results of the groups. Encourage accuracy and quantification of data. Suggest that each participant keep records of the investigation since each will later explain his or her experience to a different subgroup of the participants. Propose that each record include

- test design,
- data gathered,
- representation of data,
- interpretations and
- hypotheses or explanations.

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Cooling Works

Overview

Materials

- A variety of containers — tin cans of all sizes from tomato paste to coffee cans, plastic yogurt cups and containers, glass jars, coffee mugs, beakers and Erlenmeyer flasks*
- Covers, paper, aluminum foil, plastic wrap
- Thermometers (range 0-100° C)
- Hot water
- MBL setup with temperature probes
- Activity sheets

* Styrofoam cups are not included in this list of materials since using insulating materials can overwhelm any of the other variables that affect cooling. The coffee cans and yogurt containers come with plastic covers. These can be slit to allow insertion of a thermometer. Paper, aluminum foil and plastic wrap can also be used for covering. If it is available, use hot tap water. A disadvantage of using tap water is that everyone will tend to use the same temperature water, thus controlling that variable almost by default. As an alternative, water can be heated on a hot plate. The disadvantages of using a hot plate include limited volume, variations in the water temperature over time and safety.

Purpose and Rationale

This activity is designed to give participants a science challenge that can be approached in many different ways. The challenge is to design two containers in which water will cool at different rates. In investigating various factors that affect cooling and in deciding how to judge their experimental results, participants have to grapple with significant underlying science concepts and processes.

Synopsis

Predict the Cooling introduces the general context of hot water cooling in various containers. Time: One-half hour.

In *Testing the Variables*, participants investigate how different variables affect the rate of cooling. Time: One and one-half to two hours.

In *A Cooling Challenge*, participants take what they have learned from their initial investigations and try to achieve a greater than 15-degree temperature difference in two containers after 15 minutes. Time: One-half hour.

Participants then reflect on issues of representing and analyzing data, judging the challenge, and Where is the science. Time: One hour.

Resource Material

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Predict the Cooling

Opening Activity

This activity introduces the participants to the phenomenon of cooling and encourages them to ask questions about what factors make a difference.

How does hot water cool in different containers?

Participants form small groups of three or four, and address the question together. Provide an activity sheet or make the following steps available on a chart or the board. Have groups use the handheld thermometers for this investigation.

> ***Begin:*** *Select five different containers. Include a range of sizes, shapes and materials.*
>
> ***Predict:*** *Line the containers up according to your predicted order, warmest to coolest.*
>
> ***Test:*** *Put a thermometer in each container and pour in the hot water. Do this as quickly as possible. Read and record the temperature of the water in each container every five minutes, starting with time zero.*

I would point out to you that the most common experience of all human minds through history is "problems, problems, problems." In fact, if you're good at problem solving, you don't come to a problemless Utopia. You qualify for bigger and bigger problems.

— Buckminster Fuller,
On Education, 1979

Bring the small groups back together. Collect and display data from each group, initially just types of containers and temperatures. Encourage comments about any differences in the data between one team and another. Begin a list of suggested variables that influence the cooling.

In discussing the data preparatory to moving on to the *Testing the Variables* activity, your questions might include:

How accurate were your predictions?

What was your reasoning in choosing and ordering the containers.

If the final order was different than you expected, can you explain why?

What would you do next to explore cooling rates for the challenge?

This is also an opportunity to reflect on group process—how different groups approached the task, worked together, shared jobs, negotiated understandings.

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Exploration

What variables might minimize or maximize the cooling rate of a given container?

Testing the variables: This question should be posed in the context of planning a design for the final *Cooling Challenge*. We have found that people work best if they know the parameters of the *Cooling Challenge* before they begin, but don't let them get hung up on "the rules." It is not necessary that everyone agree on a single methodology for conducting further experiments—such a decision could limit the exploration of salient factors. However, it is hoped people will realize that some controls are necessary if they are to determine with any reliability which variables affect the rate of heat loss and by how much. Each group should have access to MBL temperature probes for these investigations.

Variables to investigate include

- *the material the container is made of,*
- *the size of the container,*
- *the initial temperature of the water,*
- *the volume of water,*
- *whether or not the container is covered, and*
- *whether or not the water is stirred.*

Circulate among the groups, observing their processes and listening to their questions, observations, etc. When questions or issues of experiment design come up, encourage each group to describe options and make the choice that seems most useful to helping them find out what they want to find out.

Looking at Limitations of the Data

Using the HRM temperature probe and software for the Apple II, here is a set of temperature readings taken every 0.18 minutes.

64.1, 64.1, 64.7, 64.1, 63.6, 63.0, 63.6, 61.9, 62.4, 61.9, 61.9, 61.9, 61.3

Two characteristics of this data stand out. One is the way the temperature readings jump around, sometimes staying steady, sometimes going down and sometimes even going up. A second characteristic is the changes in temperature—they are always a multiple of 0.5 or 0.6 degrees. Neither of these characteristics makes any sense in terms of the actual cooling process that is occurring. It does not make sense that the water sometimes gets hotter, and it does not make sense that the temperature changes only occur in half degree steps. They are artifacts of the probe and the software, i.e., of the data collecting and data recording systems. When analyzing data, it is important to recognize these shortcom-

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Exploration

Now the challenge is to set up two containers, each with hot water, so that the temperature difference between them is more than 15 degrees after cooling for 15 minutes. These are the initial conditions:

1. *The two containers are to be selected from the opening activity collection, and no additional containers or materials may be used.*
2. *The initial water temperatures must be the same.*
3. *The volume of water in each container must be the same.*

In some workshops, teachers decided as a group what initial constraints to set for the challenge. Having participants design the challenge for themselves is exactly in the spirit of project-based science.

In developing the instructions for this challenge, it seemed important to specify enough controls and give sufficient instructions so that the challenge could be successfully completed, but to leave as much leeway for each team as feasible. Thus the challenge adopts the requirement that the initial temperature and volume of water in each container be the same. On the other hand, by not specifying values for the initial volume and temperature, it is hoped teams will explore this to see what makes a difference.

Participants should use the temperature probes and software to create a graph of the temperatures in each container over a period of 15 minutes. They should print out their graph and table.

Before and during the *Cooling Challenge*, participants may raise questions about procedure and data. The most common problem is that it is very difficult to begin with the water in both containers at exactly the same temperature. Participants will have to solve that problem in either the large or small group. They may insist on everyone following the same procedure to make the test "fair." (See suggestions in the sidebar on the next page.) Important ideas about both process and content can take place during this discussion.

Someone may also raise the question of whether or not to allow insulation in the test. Again, that should be a decision negotiated by participants. Keep the discussion in the frame of "How will using insulation affect what you learn about cooling?"

Both of these design decisions will influence the data that is gathered and therefore will influence the understandings that emerge from the results.

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Synthesis

When groups have finished collecting and printing out the data, have them prepare a brief presentation along with their graph and table. They might include the following:

Explain the reasons for setting up the two containers the way you did.

Did you achieve the desired result? If not, use the graphs to describe what happened.

Given the same constraints (volume and initial temperature), how would you test your containers next time?

The biggest temperature difference may occur before or after the fifteen minute time set by the challenge. Comment on this, including why it might happen and whether or not this caveat applies to your two containers.

The results of the *Cooling Works* challenge are usually ambiguous. The challenge specifies that "the initial water temperatures must be the same." In practice, this is very hard to achieve. When the hot water is added to each container, the first use of the heat is to warm up the container. If the containers are very different, the different initial heating of the two containers can lead to different conclusions about the cooling of the water in those containers.

Since the graphs do not tend to start at the same initial temperature, how can we judge whether or not a team has successfully met the challenge?

If this concern has not already come up, the first aim of any discussion of this question is to enable participants to recognize the issue. Once acknowledged, the discussion can move on to ways of dealing with the issue. There is no one right solution; here are several possibilities:

- *Compare the overall changes of temperature in the two containers instead of only comparing the final temperatures after 15 minutes.*
- *Devise a way to ensure the initial temperatures are the same, which may then mean redoing the challenge runs (see sidebar).*
- *Compare the rates of cooling in the two containers.*

Judging the challenge by cooling rates: Since the final temperature difference is affected by the different rates of cooling in the two containers, this is a context for looking at the general concept of rate of change. Rate of change is a notorious stumbling block for math and science students of all ages. The *Cooling Works* activities can be a way to provide experiential intuition about it. The gray boxes on the next pages suggest a possible discussion that follows upon judging the contest by comparing cooling rates.

Two approaches that have come up for getting the starting temperatures the same are:

- *Heat both containers up to the hot water temperature before starting the experiment.*
- *Make sure the faster cooling container starts at a higher temperature and begin the 15-minute timing when the cooling curves cross and the two are at the same temperature.*

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Judging the Challenge by Cooling Rates

Since the graphs do not tend to start at the same initial temperature, how can we judge whether or not a team has successfully met the challenge?

An initial hypothesis is that a comparison of cooling rates at a common temperature should be analogous to comparing the overall temperature changes.

The validity of this hypothesis depends upon two underlying assumptions:

1. If one container is cooling faster than another at one temperature, it will cool faster at all the common temperatures during the 15 minutes.
2. A comparison of cooling rates at a common temperature is directly related to the final temperature difference.

The first assumption is borne out in the graphs of cooling by comparing the slopes of the graphs at points of equal temperature, i.e., points where each graph intersects a horizontal same-temperature line. Although articulating this first assumption and questioning it are not necessarily obvious steps, once raised, the graphs become a convincing answer.

The second assumption requires a caveat. It is only true if the final temperatures after 15 minutes are still well above room temperature. If both containers have cooled to room temperature, for instance, the final temperature difference will be zero, independent of whether or not the cooling rates at a hot temperature were very different. If one of the containers cools to near room temperature, this also means the final temperature difference will be less than would have been predicted by comparing earlier rates of cooling since the cooler container will have "sat still" for part of the time while the hotter container continued to cool, thus "catching up."

Both of these assumptions and their explanations depend upon understanding graphical representations. In the following gray box there are some suggested questions for facilitating a discussion about the cooling graphs and rate of change. Responses to the questions are also included as support for you as facilitator, not as *the* answers to be passed on to the participants. In a workshop, participants' graphs should be used as examples. Here we provide a theoretical graph for your information.

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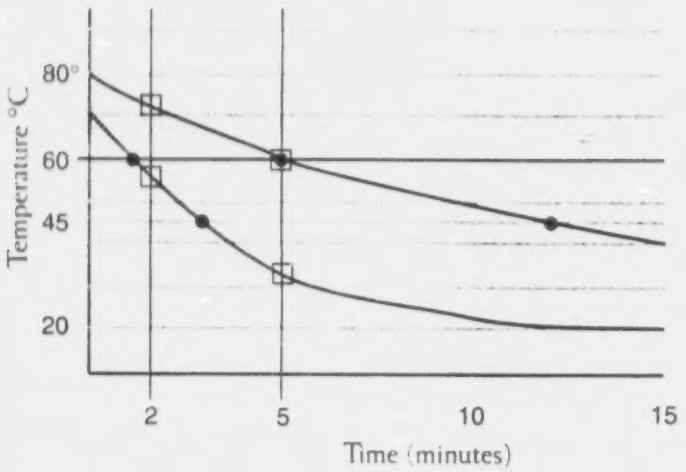
Understanding Graphical Representations: Examining Graphs of Cooling



Explain the curving shape of the graph in terms of what is happening inside the container of hot water.

Hotter water cools faster than cooler water. The shape of a cooling curve indicates that the rate of cooling slows down and approaches 0° C. When the water temperature equals room temperature, the cooling curve becomes horizontal.

If you compare two segments, one on each graph, what is the significance of any difference in steepness of the curves at those places?

The slope of the graph is a measure of the rate of change of the temperature — the cooling rate. The steeper the slope, the faster the cooling.

If you draw two horizontal lines, one at 60° C and one at 45° C, what is the significance of the pairs of points of intersection with the two cooling curves?

This shows the number of minutes each container took to cool 15 degrees. The container cooling at the faster rate takes less time to cool the same number of degrees.

If you draw two vertical lines, one at 2 minutes and one at 5 minutes, what is the significance of the pairs of pints of intersection with the two cooling curves?

This shows the change in temperature in each container over a 3-minute interval. The container cooling at the faster rate changes temperature more in the same interval.

Note Question 4 on the Cooling Challenge Activity Sheet

In the sample graph on this page the largest temperature difference occurs somewhere between 5 and 10 minutes. In general, the temperature difference gets greater until the rates of cooling in the two containers become the same. This occurs in the example graph when the faster cooling container nears room temperature and its rate of cooling is much less while the slower cooling container is still much hotter. During the last five or more minutes of the cooling in this example, the temperature difference between the two containers becomes less. It could be interesting to look closely at all the challenge graphs to see where the greatest temperature difference occurred.

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Reflecting On Practice

Opening Activity

Participants are invited to carry out the R-O-P on *Cooling Works*.

Exploration and Synthesis

Phase One. Participants work alone (or in pairs) to complete an R-O-P analysis on *Cooling Works*, using the sheet with prescribed labels and the extension sheet for their own labels.

Phase Two. Group participants into small groups to share their assessments of the activity and to discuss differences among them.

Phase Three. The *Cooling Works* activity is a very different activity from the *Watching the Drops* exercise. This will be an appropriate time to have the participants reflect on the nature of the differences between the two:

- *the advantages and disadvantages of each,*
- *ways in which they might complement each other,*
- *ideas about whether the different approaches are appropriate for different phases of a curriculum unit and*
- *how one could do Watching the Drops in Cooling Works mode and vice versa. That is to say: how would one structure the Watching the Drops activity so that it resembles the somewhat more prescribed way in which the Cooling Works activity is structured? Conversely, how would one open up the Cooling Works activity into more of a question-provoking exercise?*

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Activity Sheet

Predict the Cooling

Overview: This is an opening activity to introduce the cooling and provide an initial familiarity with the phenomenon and with the tools available for investigating it. The final goal of this series of activities is the *Cooling Challenge* which asks you to design a setup of two containers that will cool very differently.

Materials:

Containers of various sizes, shapes, and materials

5 thermometers (range 0-100° C) per team

Hot water (from the tap or heated on a hot plate)

Procedure:

1. *Begin: Select any five different containers. Include a range of sizes, shapes and materials.*
2. *Predict: Line the containers up according to your predicted order, warmest to coolest.*
3. *Test: Put a thermometer in each container and pour in the hot water. Do this as quickly as possible. Read and record the temperature of the water in each container every five minutes, starting with time zero.*

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Activity Sheet

Cooling Challenge

The Challenge: Set up two containers, each with hot water, so that the temperature difference between them is more than 15° C after cooling for 15 minutes.

Initial Conditions:

1. The two containers are to be selected from the opening activity collection, and no additional containers or material may be used.
2. The initial water temperatures must be the same.
3. The volume of water in each container must be the same.

Procedure:

1. Use the heat and temperature probes and software to get a graph of the temperatures in each container over a period of 15 minutes.
2. Print out your graph and table.

Write-up: (In addition to your graph and table.)

1. Explain your reasoning for setting up the two containers the way you did.

2. Did you achieve the desired result? If not, use the graphs to describe what happened.

3. Give the same constraints (volume and initial temperature) how would you design your test next time?

4. The biggest temperature difference may occur before or after the 15-minute time set by the challenge. Comment on this, including why it might happen and whether or not this caveat applies to your two containers.

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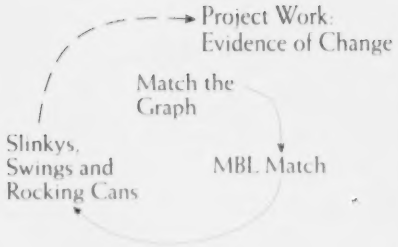
Overview

Exploring Motion



Materials

- Duplicated or enlarged copy of MBL graphs of motion (See page 68)
- Computers with distance probes and printers for each group
- Leader demonstration computer (with projection system, if available)
- String, clothespins, various weights, ring stand
- Paper clips
- Masking tape
- Index cards
- Slinkys of different sizes
- Coffee cans and cans of different sizes
- Wide rubber bands
- Clay (weight inside can)

Preparation

See the Activity Sheet for setups of the three MBL stations for *Slinkys, Swings and Rocking Cans*.

Resource Material

Purpose and Rationale

There are many kinds of motion — the flight of a bird, the stride of an animal, the turning of gears. These activities explore how objects move and how these movements can be represented graphically. The emphasis is on reading and interpreting graphic representations of motion — change in position over time. In a broader sense, participants continue to address the issue of change and how it is represented.

During the opening experience, participants act out graphic representations of motion. The linking of representation with experience helps them extend their understanding of how graphs are read and interpreted, and provides firsthand experience with the phenomena. Using MBL, participants see their own motions recorded as they move in front of the distance probe, which again links abstract representations with experience and provides opportunity for understanding how the MBL software represents and supports interpretation of data.

Synopsis

In an activity similar to charades (*Match the Graph*) the participants interpret graphic representations of motion by acting-out one of six graphs. Time: One and one-half hours.

The MBL distance probe is then introduced and the participants attempt to construct a graph that matches one of the six graphs using the MBL (*MBL Match*). Time: One hour.

This leads to a series of experiences in which participants use *Slinkys, Swings and Rocking Cans* to further explore ideas about motion. These experiences all set the stage for doing independent projects. Time: Two and one-half hours.

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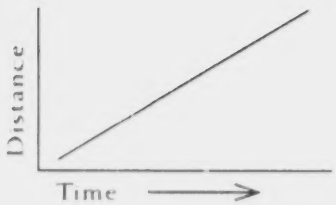
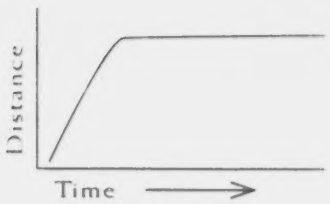
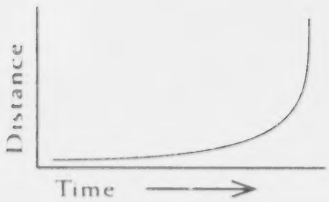
Match the Graph







Opening Activity

In this first activity participants explore motion and how motion can be represented. Display the six "Graphs of Motion Over Time." (Activity Sheet, page 68). Then ask the participants (working in small groups) to find a way to physically act out one of the graphic representations so that others can guess which one of the graphs represent their actions. This can be thought of as a variation of the game charades.

Participants will need 10 to 15 minutes to decide on a way to act out their graph. For example, they might show motion by moving back and forth. It is not always obvious to learners that time is being represented by the graphs. Suggest that participants think about how much time the graph might represent as they act it out.

Groups then come together and play out the particular graph they chose. Others make observations and ask questions about the movements and then guess which graph is being represented.

If more than one group worked with the same graph, consider the similarities and differences in how they chose to enact the graph. Questions for discussion might include:

What trends or patterns did you notice in the movements?

What makes you think that the movements represent that particular graph?

Exploration

Explain that the distance probe is a tool that can help a learner to explore motion. Briefly introduce and model how the probe works (see background information). Be sure that participants know the range of the probe and that the probe can pick up better data from a large, flat object than from a small, curved object.

Adjust the time and detail of the explanation depending on how familiar and experienced participants are with other probes. For example, if participants have used the temperature probe extensively in former investigations, then your demonstration might be limited to a quick introduction of the probe, its potentials and limitations.

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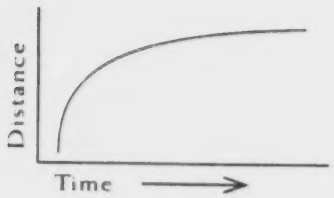
Introducing the Distance Probe

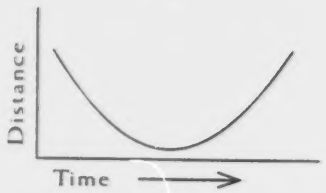
Be sure that the participants know

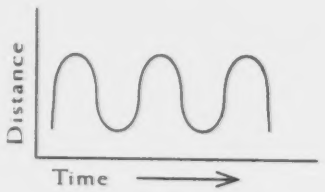
- *how to run the program.*
- *how to move through the menus on the software.*
- *what the limitations of the probe are and*
- *how to save and print data and graphs.*

To provide a context for the participants' initial explorations, invite them to try to recreate the graphs provided for the *Match the Graph* activity using the MBL.

To again emphasize the concept of change, suggest that the participants consider whether each graph represents steady, cyclical or irregular change in motion. Suggest that they try to create their own MBL graph showing evidence of each kind of change.







Synthesis

Provide a forum in which participants can discuss issues about the tool and their learning. Issues might include:

How did the real-time data provided by the MBL support the development of understandings about motion and about graphic representations?

What mathematics was involved in your experience? What science? How do the two disciplines interface in this experience?

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Slinkys, Swings and Rocking Cans

Opening Activity

How are the motions of a slinky, a rocking can and a swing alike and different?

To help answer the question, ask the participants to use the MBL distance probe to create graphic representations of the motion of a rocking can, a swing and a slinky, and then to compare and analyze their MBL graphs for the three objects. Anticipate that it will take time for the participants to figure out how to use the MBL effectively. They will need to do tests several times, revising their strategies and setups.

Instruct the participants to make printouts of their MBL graphs. As you move from group to group during the explorations, ask the participants to explain their printouts. Help them to consider range, frequency and variation in their explanations.

In our experience, participants begin to ask and investigate their own questions during this initial exploration. Many of the questions that emerge relate to variables that affect the motion of an object. For example, in the case of the rocking can, participants might ask: Does the size of the can or the amount of weight change the motion? These "side trips" in the exploration are exactly what one would hope would happen. However, as time comes closer for bringing the groups together again, encourage the participants to return to the original task — to make and interpret at least one MBL graph for each of the three objects.

During a whole-group session, have the groups share their explorations and findings. Groups will have had different experiences and will have explored different factors. Sharing these experiences sets the stage for further investigation.

During an all-group discussion, it may be helpful to read and interpret an MBL graph together noting time, distance, scale, frequency, variation and range. One technique is to make an overhead of one or more graphs created during the group explorations and then have everyone participate in the interpretation process. This modeling may deepen understanding of how to glean information from graphic representations. It may also provide participants with a strategy for supporting children's work with graphs in the classroom.

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Exploration

Invite the participants to identify a question of interest to all members of their group and to investigate further. This second phase of investigation is important. After hearing about other groups' experiences, the participants will have new questions to explore. One group's findings often become another group's investigation, thus participants experience their own learning being enhanced by that of their colleagues.

Note: Some participants may find it interesting to try to recreate the motion of the slinky, swing and rocking can with their own bodies.

Synthesis

As part of an all-group discussion, ask the participants to consider how their explorations and investigations have contributed to their understanding of motion and change. It is important to expect that conceptual understandings will be extended through their experiences. Discussion questions might include:

What did the distance probe show you about motion that your eyes (or other senses) could not?

What learnings were there for you?

Were there mathematical as well as science learnings involved? Where is the interface between science and mathematics in these experiences?

What do you think elementary school children should learn about motion? How could the MBL motion probe support their learning?

The Distance Probe

Can technology support the development of understandings that are not easily addressed with young children?

With more emphasis on reading and interpreting graphic representations, might the concepts of speed and velocity become accessible to elementary school children? For example, if we were to ask learners to create a graphic representation of speed over time for the situations represented in *Graphs of Motion One and Two*, what representations and explanations would result? MBL software packages can readily transfer distance-over-time data to speed-over-time data. Might this function be introduced to elementary school children, or is it too much of a conceptual leap? While the appropriateness for young children is open to debate, graphic representations of speed would be appropriate and challenging for adult learners.

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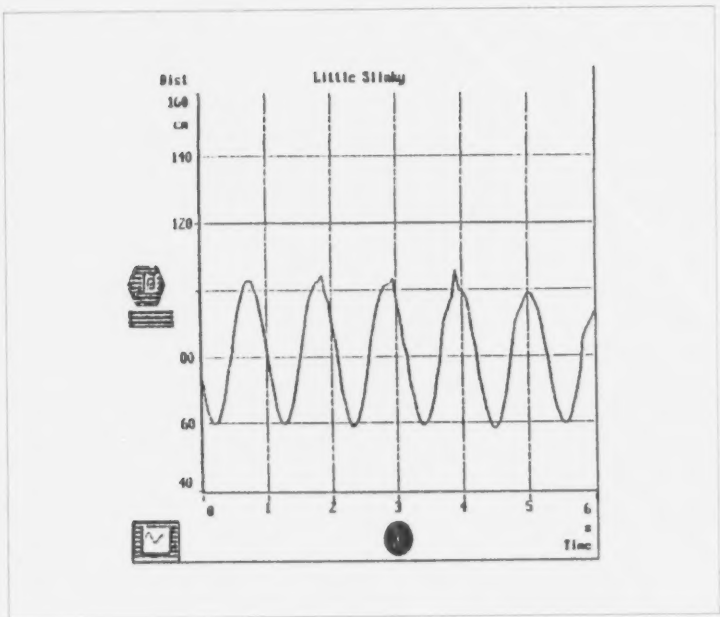
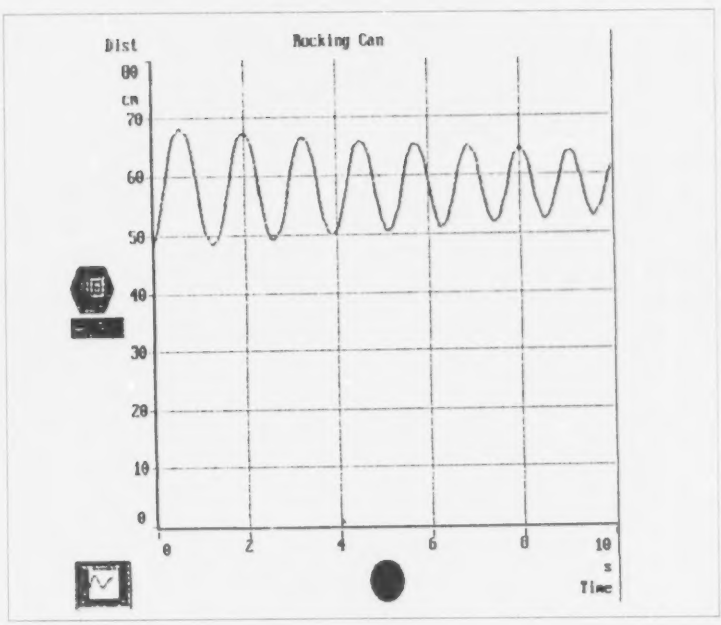
Teacher Workshop Experience

During one teacher workshop, participants talked about the conceptual understandings used during their explorations. Concepts such as gravity, force, friction, vectors and energy transfer. Mathematical concepts were mentioned as well. One teacher suggested that students' understanding of circumference and diameter might be meaningfully addressed if students were to explore the relationship between can diameter and rocking.





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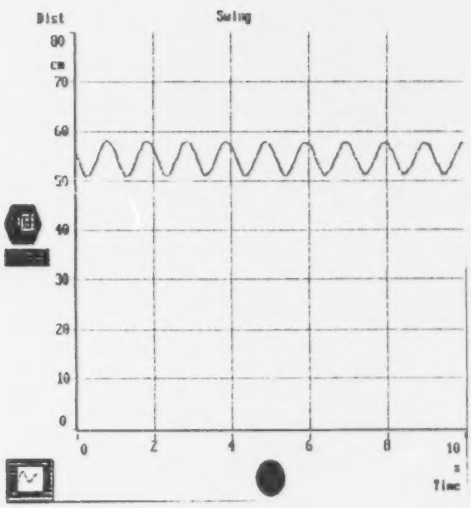
Participants' Data on Motion



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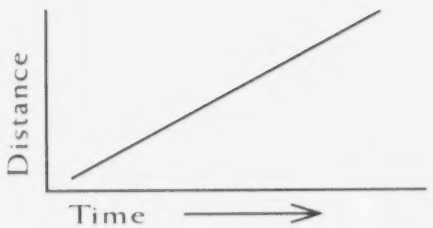
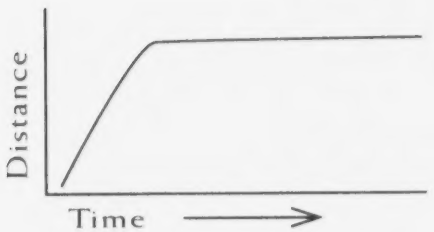
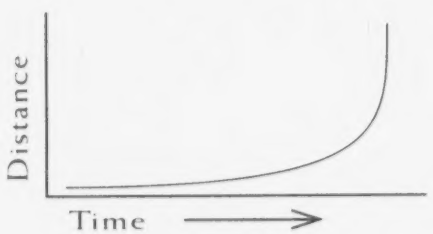
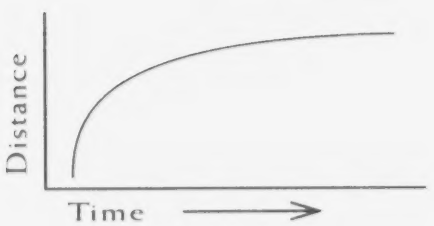
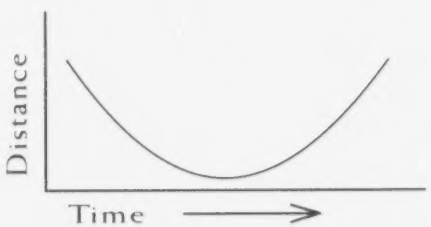
Activity Sheet

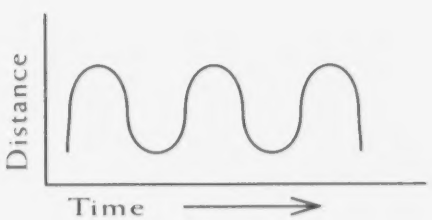












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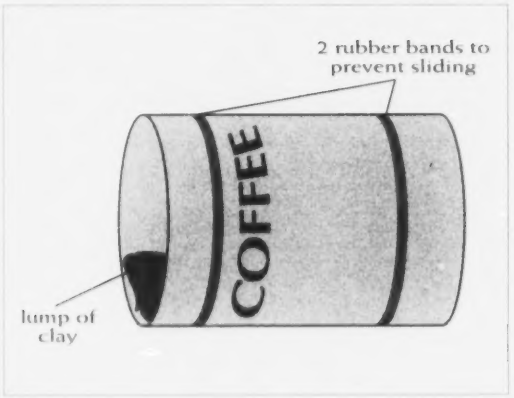
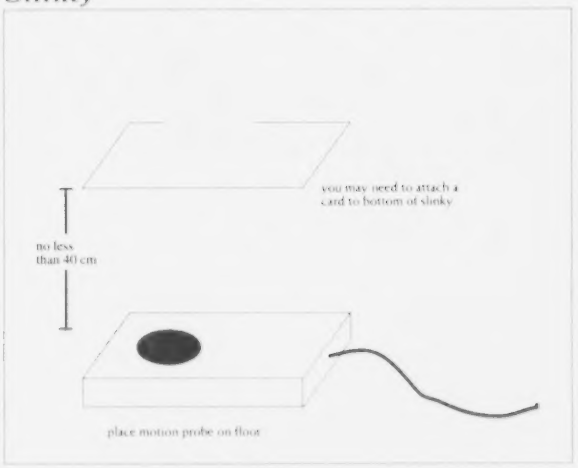
Activity Sheet

Rocking Can



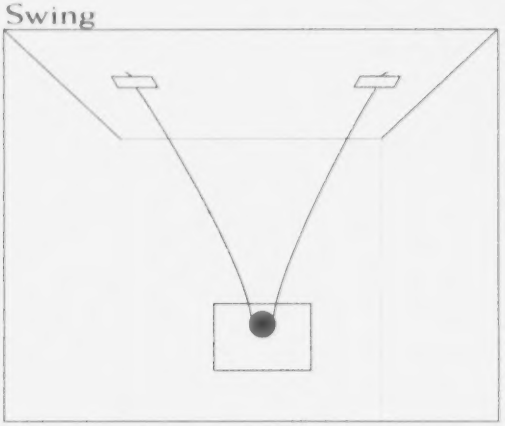
The rocking can may be made by placing two rubber bands, one on top of the other at each end of the can and attaching a lump of clay to the inner curved wall of the can. The can will need to be placed at least 40 cm from the motion probe.

Slinky



Place the motion probe on the floor. Let the slinky drop from your hand toward the probe (no closer than 40 cm). You may obtain better results by attaching a flat card to the bottom of the slinky.

Swing



The swing can be made by attaching a string in 2 places on the ceiling and then hanging a weight in the middle. You may need to attach an index card to the weight for the probe to see.

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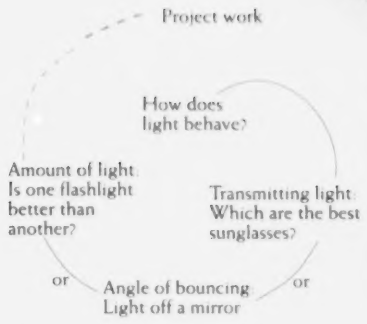
Overview

How Does Light Behave?


Project work
How does light behave?
Amount of light: Is one flashlight better than another?
Transmitting light: Which are the best sunglasses?
or
Angle of bouncing Light off a mirror
or

Materials for the Circus of Activity

Leader demonstration computer (with projection system, if available)

Computers with light probes and printing capability for each group

(Optional) Computer set up with one temperature probe and one light probe that have been collecting data over the period of a few days

Materials

Place the materials on a table for groups to access as needed:

2 to 4 small lamps
10 or more pairs of sunglasses
10 mirrors
4 tennis balls
yarn
4 shoeboxes
rulers
scissors
masking tape, scotch tape
10 flashlights
presentation aids: markers, chart paper, acetate for the overhead

Optional:

shoe boxes
colored cellophane or transparent plastic
food coloring, water, eye droppers, small glass containers
different kinds of paper, e.g., rice paper, tracing paper

Purpose and Rationale

The main purpose of these activities is to use the MBL light probe to extend understandings about light — in particular, amount of light transmitted by and through objects and change in the direction of light or angle of reflection. A second purpose is to introduce an alternative instructional strategy that can be used in the classroom.

It will be a rare classroom that has enough MBL equipment for all students to use the tool at the same time. As well as providing a way to open up the learning environment and to work with multiple aspects of a problem or phenomenon, this unit also models an instructional strategy referred to as A Circus of Activity in which one or two groups of students are engaged with MBL while others are involved in nonMBL activities. The Circus of Activity varies from the traditional learning center model in that all students are addressing one overriding question or problem, in this case, How does light behave? Groups may work through several of the activities, all of the activities, or only one of the activities depending on the teacher's goals.

Synopsis

Following an introduction to the light probe, participants engage in a series of three activities that explore the transmission and measurement of light. They then share their experiences and consider the relevance of "the circus" as an instructional strategy for the classroom. Finally, they view a video case study in which third graders use the MBL light probe to extend their understandings of light. Time: Introducing the Light Probe (10–30 min.) Circus of Activity (One and one-half–two hours); Video Discussion (40 minutes).

Resource Material

Page A-11-12

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How Does Light Behave?

Opening Activity

Introducing the Light Probe: Begin with a brief demonstration of the probe. Show how the MBL represents changes in light intensity by moving the probe in and out of a dark box or area.

Break into groups of two to four at each computer. Ask the participants to find out about the light intensity in their own work area by using the probe to gather data about the amount of light at three or more locations. Is the amount of light the same? How much variation is there? This brief exploration will provide opportunity to address questions and issues about the tool that may be common to all groups.

Since light intensity may vary greatly from one location to another, the axis range (on the MBL graphs) may need to be reset. Anticipate that participants may need help with this.

Exploration

Once all are comfortable with the technology, pass out the activity sheet and explain the procedure for doing the circus. Introduce each question. Invite the groups to choose one question to investigate. If time permits, groups may move on to a second question, but set the expectation that each question should be explored fully.

Which are the best sunglasses?

How does light bouncing off a mirror compare with a ball bouncing off a wall?

Is one flashlight better than another?

Choosing which graph type to use will depend on how a group decides to define "best." For example, to determine whether one flashlight is better than another, a group may decide to gather data about the amount of light transmitted by each flashlight when it is turned on. In this case, a bar graph would be the best way to represent the data. If, however, the group decides that "best" should be determined by how much light is transmitted over a 5-minute period by each flashlight, then the best choice of graph type is a line graph representing change over time. Choosing the appropriate graph type may be intuitive for the adult learner, but not necessarily for the young learner. Have the participants explain how they are deciding which graph type to use.

Encourage the participants to consider the kind of graph they will use based on the nature of the data. There are times when participants will want to gather data over time with the light probe, for example, gathering data about the amount of light at the window sill over a 24-hour period or testing whether a flashlight or lamp gives off a consistent amount of light during a 20-minute period. However, at other times, the data are discrete, for example, in testing different colored filters to determine which transmits the most or least amount of light.

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Synthesis

As each group shares experiences, consider the following questions:

How have understandings or questions about light changed?

How did the MBL light probe support learning?

What kind of learning environment did the Circus of Activity create?

Does having different groups engaged in different tasks change the learning atmosphere?

The Circus of Activity is an instructional strategy that can be used in the classroom to explore various aspects of a phenomenon. It also addresses a common logistical problem of not having enough MBL set-ups for all groups to work with at the same time. While the MBL may be used in all activities in this case, a circus could be designed that involved one MBL activity and several nonMBL activities.

Video — Classroom Case Study*: In the video, third graders investigate how much light is transmitted through colored filters and sunglasses. The case study might be used to consider how a teacher supports students' learning. Discussion following the video might include:

What kind of questions does the teacher ask?

What role is the teacher playing?

Children may have wonderful ideas, but they may not yet have the skills to express their ideas well. How does this teacher support students in clarifying and expressing their ideas?

Extension

Invite the groups to design and carry out an investigation about a question that is of interest to them. Encourage them to go beyond the original set of questions. Emphasize that their question needs to be of relevance to them as adult learners. The intent is for their investigation to further their own understanding of light. Provide a variety of materials as suggested in the materials list.

* Optional. The videotape of case studies is available from TERC, 2067 Massachusetts Ave., Cambridge, MA 02140; telephone 617-547-0430.

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Activity Sheet

Circus of Activity: How Does Light Behave?

With other members of your group, explore one of the following questions. The questions are designed to extend your understanding of light and to help you to consider your own questions about light and how it behaves. Use the light probe to help you with your investigations. It is important not to rush your experience.

Transmitting Light — Which are the best sunglasses for a life guard?

Angle of Bouncing — How does light bouncing off a mirror compare with a ball bouncing off a wall?

Amount of Light — Is one flashlight better than another?

Please plan to share

- *which question you investigated,*
- *how you went about addressing the question,*
- *interpretations of the MBL graphs you produced,*
- *what your findings were as evidenced by the graphs and*
- *findings and new questions related to light.*

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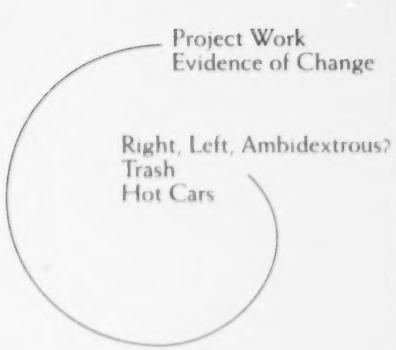
Overview

Project Work: Evidence of Change



Purpose and Rationale

In these activities, participants explore their own question about change in motion, temperature or light; they directly experience project work and extend their understanding of MBL as a tool for gathering and analyzing data.

Our premise is that participants need to experience project work to understand its value and how to support its use with students. This experience also provides opportunity for participants to become more familiar with the potentials and limitations of the MBL.

Synopsis

Working in small groups, participants choose a question and plan an investigation based on their experience with: skin temperature, heating and cooling, melting Popsicles, matching the graph, slinkys, pendulums, rocking cans or light. Guidelines are that the investigation must explore change and that the MBL should be used to help gather data about this change.

Each group plans their investigation and then shares their plan with another group for ideas about how the investigation plans might be further refined. Time: Two hours.

Groups carry out their investigations and are then invited to exchange investigations with another group. Time: Two hours.

Finally, groups compare experiences and reflect on their learning. Time: One hour.

Materials

- Computers, probes and printers
- Large paper and colored marking pens for representing data, presenting investigation results and creating visual representations
- Materials provided for the other activities
- Additional materials as requested by participants and as available

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Project Work: Evidence of Change

Opening Activity

List the topics participants have worked with on chart paper or on an overhead. Together generate a list of questions that have emerged from the earlier investigations. Once a substantial number of questions have been generated, invite the participants to choose a question to pursue in more depth. The chosen question should explore the concept of change. Encourage participants to use the MBL to help gather and analyze data. Invite participants with similar interests to work together.

Questions Generated in Other Workshops

Does the amount of weight make a difference in how the can rocks?

Does the length of the chain make a difference in how the swing moves?

Does the weight of the person on the swing make a difference in motion?

Do different springs behave differently?

Would different slinkys move differently?

How does the motion of a windup toy change with different a number of winds?

Exploration

The investigation process will at first be exploratory in nature. Groups may try several ideas or want to work with several questions. This is their opportunity to become more familiar with the MBL by using it to address their own questions.

As the facilitator

- help the participants to get the materials they need;
- if there are useful features of the MBL with which participants are not familiar, provide on-the-spot instruction;
- encourage the participants to explore more extensively the capabilities of the MBL software for analyzing data;
- if a group continues to explore randomly, help them to focus their efforts;
- enquire about what question they are investigating and how they are designing their tests;
- encourage the participants to stay with their own learning — opportunity to design ideas for the classroom will come later;
- set and communicate time limitations.

Peer Review: After the groups have a developed plan, suggest that they ask another group for feedback. This peer review provides a forum for reflection and revision during an experience rather than after all work is complete.

Questions that reviewers might ask: What is the original question? How are you planning to test it? What evidence will you look for?

Questions that designers might ask: Are there suggestions for fine-tuning our plan? Are there alternative strategies you can identify?

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Synthesis

Since one of the "tests" used in scientific research is to repeat investigations looking for consistency in the results, an alternative to project presentations could be to have two groups trade investigations and carry out the other group's test. Sharing would then involve the two groups comparing their experiences:

How do our data compare?

Did we come to the same conclusions?

What were the issues in trying to duplicate research?

If this strategy is used each group will need to prepare detailed instructions for carrying out its investigation.

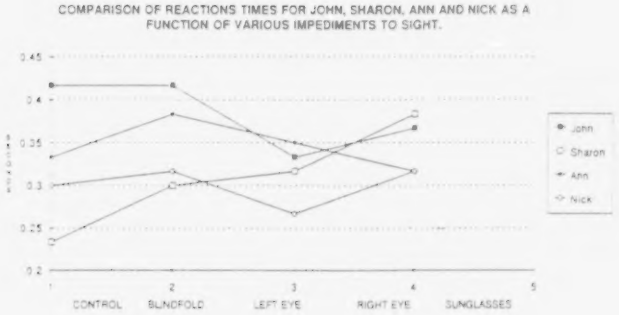
Reflection

As participants discuss their project work experience, encourage them to reflect on their own learning process.

What assumptions did you have about the phenomena being investigated before you started? What "laws" or "principles" did you have in mind? Change in our understanding of these assumptions is what constitutes science learning. What assumptions or beliefs have changed for you as a result of your investigations?

What learning opportunities does project work support that other instructional strategies may not?

REACTION TIMES GRAPH



Questions about Melting Popsicles

If you vary the amount of sugar in the Popsicle, will it melt differently?

Does the inside melt at a different rate than the outside? How do they compare?

How does a Popsicle freeze? How long does it take?

Does the shape of the Popsicle make a difference in how it melts?

How will the water temperature change when an ice cube is added to a glass of water? — A glass of Coke? Will it vary with different amounts of water? Different water temperatures? What happens if the ice cube is added to hot water?

Questions about Change Related to Light

How does the amount of light transmitted through water change as drops of ink or food coloring are added?

Is the amount of light produced by a flashlight consistent over a set time frame?

How does the amount of light produced

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Overview

Introduction to Telecommunications

The following set of activities are designed to introduce participants to telecommunications through their own learning and also to raise and address various issues related to using telecommunications to support elementary science learning in the classroom. As in the MBL section, the activities *Left, Right or Ambidextrous, Trash,* and *Hot Cars* each explore a different aspect of science content and process using the technology and leave participants with a set of questions that they may pursue in the *Project Work* activity. The use of telecommunications to support teachers as they develop a reflective community beyond the walls of the workshop is addressed in the implementation activity, *Professional Discussion On-line.*

Note that *Hot Cars* further explores concepts of heat and temperature and thus extends participants' experiences from *Cold Hands/Warm Heart?, Cooling Works,* and *Representing Change: A Melting Popsicle. Hot Cars* can also be implemented with both MBL and telecommunications, if you are very adventurous.

Notes for Implementing Telecommunications in a Workshop Setting

The *Resource Material on Telecommunications* in the back of this manual is designed to give both you and your teachers a general overview of the technology and its application to elementary science learning. We also provide information on vendors and costs. The following information relates specifically to planning, setting up and running a teacher workshop.

Resource Material

Pages A-15–20

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Introducing Telecommunications in a Staff Development Setting

We have used two different types of communication networks to introduce elementary science teachers to telecommunications: Local Area Networks (LANs) and distance networks (also known as Wide Area Networks or WANs).

In our experience, it has been difficult to motivate a need for telecommunications in an intensive one- or two-week workshop setting. When it is possible to convene a group discussion around a question or to go into the next room to speak to someone, conducting an asynchronous dialogue in which responses are written, read and responded to over an extended period of time is at best tedious, and at worst detracts from the work at hand. Simple, easy-to-use LAN software can minimize some of these barriers during a structured activity. However, discussion around complicated or difficult concepts should still take place in person lest participants become frustrated with the technology.

The potential value of long-distance networking becomes more apparent *after* the workshop. Classroom or student investigations involving several distant classrooms can have the advantage of extending the resources of the classroom in myriad ways. Perhaps more importantly, we know that change in teaching practice takes time and ongoing support. When workshop participants have returned to their different (and distant) school settings, telecommunications can be an effective way for them to keep in touch with colleagues who are struggling with similar challenges as they try to shift their professional practice.

Pros and Cons of Using a Local Area Network

We use the Local Area Network as a training tool in these activities to simulate long-distance communications. This is because LAN software tends to be easier to use. Because it is self-contained as long-distance networks are not, a LAN may be controlled more easily by the workshop trainer. Some technical considerations are more easily managed; for instance, access to direct outside telephone lines is not needed. In addition, the concept of distance communication is easily understood by participants as they communicate with others in the next room, and it generally helps them feel at ease with the technology.

However, a LAN does not provide a true example of what long-distance telecommunications "feels" like; nor does it provide access to the resources that a distance network can provide. And without exposure to a long-distance network, participants may remain focused on local uses of telecommunication.

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If you do not have access to, or prefer not to use, a Local Area Network, you can substitute e-mail communication over any long-distance network which delivers e-mail without delays (see Pros and Cons of Using a Long-Distance Network below).

Pros and Cons of Using a Long-Distance Network

Even if you use a Local Area Network in a workshop to simulate long-distance collaborations, we strongly recommend that you introduce participants to actual long-distance networking for research and information gathering. This is a critically important feature of telecommunications that a Local Area Network usually cannot simulate.

The challenges to using a long-distance network in a workshop setting are many. First, you will need access to a direct, outside phone line(s) and the money to pay for your online access. Then, you need to rely on this phone line being available and working, as well as having the correct access number for the services, and an alternative plan for what to do if the host is busy or out of service. Finally, you must be familiar and comfortable with how to navigate within the network structure and use the services. This is easier to do on a commercial network such as America Online or CompuServe than it is for the Internet.

We suggest that you introduce participants tolong-distance telecommunications by accessing ERIC. Information and instructions are located in an Activity Sheet in the *Project Work using Telecommunications* activity.

When Setting Up Telecommunications Stations for the Workshop

- You will need sufficient access to technology for all participants. We recommend at least one completely equipped computer station for every three to four participants.
- It can be confusing if more than three teams are communicating with one another (e.g., if there are more than three telecommunication stations), particularly if this is the participants' first experience with telecommunications. If you have more than three teams, we recommend that the teams be split into subgroups of no more than three teams each for the purpose of these activities. This will reduce the confusion that can arise when many teams try to communicate in near-real time.
- Set up and test all telecommunication stations completely before demonstrating the software to participants. This includes cable hookups, software settings, modem connections.

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- When using a long-distance network, have alternate access numbers ready in case the first number fails. It also helps to have spare parts of all kinds available — modems, cables, even a computer if possible.
- Telecommunications stations should preferably be set up in different rooms, or at least partitioned out of view from one another. To further develop the simulation, you may want to "name" stations after geographically distant regions — e.g., Cleveland, OH; Reading, CA; Birmingham, AL.

When Introducing Telecommunications in the Workshop

- Before the workshop begins, prepare and send a "welcome message" to all telecommunication stations (or accounts). The message should request a short response, for instance, that each team communicate the names of its group members to the other stations.
- Provide participants with a simple, one-page "crib" sheet which explains how to use the most important functions of the software: picking up and reading mail, composing and sending mail.
- Model use of the software, demonstrating that it is easy to use. Particularly if participants are new to telecommunications and to the software, show them only the functions they will need for the activity, specifically, how to send and receive text messages. Even simple software is typically much more powerful than new users require.
- Ask participants to pick up and respond to their "welcome message" before they begin their activity.

Facilitating a Telecommunications Workshop Activity

As workshop leader you have the option of setting up a telecommunications station for yourself so that you may intervene online if necessary. However, providing an activity timeline can help to keep participants on track and may obviate much of the need for online intervention. (Adding one more party to the communications may make the discussion more confusing.) In addition, it may be preferable to check in with each group personally in order to answer technical or other questions.

In general, when participating in telecommunications activities that are more open-ended, teams must actively take the responsibility upon themselves to make sure that they understand one another — confirming communication by repeating questions and requesting clarification. Your role is to guide them in this direction even if that requires stepping back and letting them encounter and solve problems of how to communicate effectively.

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Overview

Right, Left or Ambidextrous?

Materials

- Something to kick — a plastic wastebasket is ideal
- Index cards with a hole made with a pencil
- A large pad or pads for recording the initial data
- 12" ruler or longer for optional Ruler Drop Test
- Computer connected to a printer and with a spreadsheet template set up for collating and analyzing the data
- Activity sheets
- Copies of *Science and Children* article

Resource Material

Page 88

Purpose and Rationale

This activity focuses on data collection and data analysis. The context is handedness, and the data people collect is interesting, but it is also complex. It raises questions about how good the tests are, what correlations exist between the tests and how to interpret data that shows trends but not 100 percent answers.

One of the strengths of telecommunications is that it can be used to support distributed data collection — the gathering of many pieces of information distributed over a wide geographic area, from a large data pool. This has been the focus of many telecommunications-based curriculum activities. However, TERC's experience has been that students and teachers are interested in collecting and sharing data but then often do not take the next step of looking at and analyzing the collated data from all classrooms.

This activity helps participants focus on data analysis by providing a model of an in-depth discussion centered on data that has been collected by the teachers and then collated with and compared with shared data from others. The complex data set that results from investigating this seemingly simple question opens up important questions about looking for patterns and selecting appropriate sample size.

The workshop facilitator's role in modeling the data analysis discussion among participants is critical. In the Synthesis section, we have included questions which may be helpful to prompt a discussion. Using telecommunications to expand the data pool is optional.

Synopsis

Participants are presented with the question: Are people in this group right brain dominant, left brain dominant or ambidextrous?

Given a series of tests, participants gather data from themselves and others. They then work in small groups and with the whole group to make sense of the complex data.

The data analysis will lead to reflection on a number of issues, including how accurate are the tests, how does one manage large, messy data sets and how can telecommunications support a scientific investigation.

Time: Three – four hours. (If the work is extended to include data collected at home, additional time for sharing and analysis will be needed.)

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Right, Left or Ambidextrous?

Opening Activity

Present the group with the question:

Are people in this group right-brain dominant, left-brain dominant or ambidextrous?

Give everyone the Activity Sheet initially but hold the article from *Science and Children*, which includes the data on the 50 sixth graders, until people have shared analyses of their own data.

Decide on a question. Except for *The Ruler Drop*, the tests listed below are the ones used by Andrea's class to collect their data. Using these same tests is important if you are to compare data with others.

- Are you right- or left-handed? Test: Which hand do you write with?
- Are you right- or left-footed? Test: Which foot do you prefer to kick with?
- Which is your dominant eye? Test: Hold a card with a small hole in its center at arm's length. With both eyes open, look through the hole at a point in the distance, say across the room. Next view the point with one eye closed and then the other eye closed. Do not move the card or your head. With which eye could you still see the point?
- Which thumb comes out on top? Test: Which thumb comes out on top when you intertwine your fingers by clasping your hands?
- Optional Additional Test: The Ruler Drop. Working in pairs, collect data on how far a 12-inch ruler or a meter stick drops before the person catches it between thumb and forefinger. Start with ruler held between a person's outstretched thumb and forefinger. Compare measurements for left and right hands.

Try out the tests on yourselves.

Agree on a table format for recording the data.

Collect data. The tests are short and people tend to find them interesting, so it is easy to include people who are not even in your workshop.

Telecommunications

Another way to increase the size of your data pool is to have participants post their data collection questions on a network bulletin board service (BBS). Before they post their tests and questions, participants should make sure that they have described the test clearly. One way to help ensure clarity is to conduct a "trial run" of the message within the workshop. *NOTE: Refer to "Tips for crafting a 'message in a bottle'" p. 105, for more notes on composing messages for a public BBS.* Final data analysis results should be shared over telecommunications with any responders.

Exploration

Collate the data: If possible, use a spreadsheet set up on a computer connected to a printer (see the suggested spreadsheet layout on the following Resource Material page).

Analyze the data: Working in small groups, see what conclusions can be drawn from the data and what conclusions cannot be drawn (typically referred to as further questions.) Collate small groups' conclusions and questions. Then compare with the *Data from Sixth Graders* collected by Andrea's class.

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Synthesis

The objective of this activity is to focus on data analysis. The data people gather is interesting, but it is complex. This combination of interesting, rich, and complex data stimulates a lot of discussion, which is just the point. For instance:

What are the tests really measuring? The thumb test, in particular, is one people have questioned. It is easy to do, but does it measure right/left dominance? A closely related test is to ask people to clasp their hands, palm to palm, which thumb comes out on top? In many cases, but not all, the thumb on top when clasping turns out to be the opposite of the thumb on top when intertwining hands. Is one of these tests better than the other? In the "intertwining" test, is the dominant thumb the one that grasps the opposite forefinger rather than the thumb which is on top? Do either of these have anything to do with right/left dominance? This last question could lead to a whole mini-investigation.

What about people who are ambidextrous? Nothing in the initial data collection tests includes this category. Typically there are two paths to ambidexterity: people who are naturally ambidextrous and people who have been trained to use both their left and their right. This later group includes both natural lefties who have been trained to use their right, and sports people who have been trained to use both, such as a soccer player who needs to be able to kick with either foot.

What are correlations between tests? One of the complexities of the data is that there do not seem to be any absolutes; for instance, not all right-handed people are right-footed. Analysis, therefore, involves looking for trends. What proportion of the people are left-handed? Of the people who are right-handed, what proportion are also right-footed? Left-footed? The article from *Science and Children* includes a two-way comparison chart (Figure 3) which can be difficult to understand, especially before you have done any correlations on your own. We suggest waiting until the end of this activity before referring to it, if at all.

When is a data sample large enough to justify drawing conclusions? For instance, in one workshop, data was collected for nineteen adults. See *The Ambidextrous Spreadsheet* in Resource Material, p. 88. If you compare this data with the data from Andrea's classroom, some of the percentages are different. For instance, 78% of the workshop people were left-thumb dominant compared to 68% in Andrea's sample. Is that difference significant?

The Two-Sided Man

Much I owe to the lands that grew —
More to the Lives that fed —
But most to the Allah Who gave me Two
Separate sides of my head
Much I reflect on the Good and the True
In the faiths beneath the sun
But most upon Allah Who gave me Two
Sides to my head, not one
I would go without shirt or shoe,
Friend, tobacco, or bread,
Sooner than lose for a minute the two
Separate sides of my head!

Rudyard Kipling

The main theme to emerge... is that there appear to be two modes of thinking, verbal and nonverbal, represented rather separately in left and right hemispheres, respectively, and that our educational system, as well as science in general, tends to neglect the nonverbal form of intellect.

Roger W. Sperry, 1973

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Activity Sheet

We all know that most people are right-handed, and what is more, for those who are left-handed, we all realize that "training to use your right hand" can be damaging. The latter is a recent understanding, and there are typically adults in any group who have bad memories from childhood. This activity looks at data related to this whole question. The initial idea is from an article in the journal, *Science and Children*, October, 1986.

"My daughter came home from school recently, excited but confused. Her sixth grade science class had been learning about the human nervous system during the week, and on this day they had discussed the left and right hemispheres of the brain. The teacher carefully led the class through the functions of the two sides. He mentioned, for example, that in most people, speech is directed from the left hemisphere and imagination from the right. The class also found out that though the two hemispheres generally divide the cognitive functions between them, one of the two hemispheres — the dominant one — seems to play a much larger role in directing a person's day-to-day motor and sensory activities.

"Furthermore, students learned, the nerves from one side of the brain cross to the other side of the spinal cord. As a result, a person whose left hemisphere was dominant would favor the right side of his or her body and vice versa. Each student immediately began testing for hemispheric dominance by noting which hand he or she used in writing. All told, my daughter's science teacher had conducted an outstanding lesson, one that generated excitement and enthusiasm.

"But as the day went on, my daughter became confused. After leaving science class, she began to wonder whether she had determined her dominant hemisphere. Initially she had concluded that since she wrote with her right hand, her dominant hemisphere was on her left side. But during the next hour in gym class, she discovered she preferred to kick a soccer ball with her left foot. Had she learned to kick with her wrong hemisphere?"

— Thomas R. Lord

From "Right-Handed and Left-Footed? How Andrea learned to question the facts." *Science and Children*, October 1986

Decide on a question. The tests listed below are the ones used by Andrea's class to collect their data. Using these same tests is important if you are to compare data with others. The last test, *The Ruler Drop*, however, was not used by Andrea's class.

- Are you right- or left-handed? Test: Which hand do you write with?
- Are you right- or left-footed? Test: Which foot do you prefer to kick with?
- Which is your dominant eye? Test: Hold a card with a small hole in its center at arm's length. With both eyes open, look through the hole at a point in the distance, say across the room. Next view the point with one eye closed and then the other eye closed. Do not move the card or your head. With which eye could you still see the point?
- Which thumb comes out on top? Test: Which thumb comes out on top when you intertwine your fingers by clasping your hands?
- Optional Additional Test: The Ruler Drop. Working in pairs, collect data on how far a 12-inch ruler or a meter stick drops before the person catches it between thumb and forefinger. Start with ruler held between a person's outstretched thumb and forefinger. Compare measurements for left and right hands.

Try out the tests on yourselves.

Agree on a table format for recording the data.

Collect data. The tests are short and people tend to find them interesting, so it is easy to include people who are not even in your workshop.

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Activity sheet

Data from Sixth Graders

Results of a Survey Showing Body Dominance of Four Traits in 50 Sixth Graders

Subject	Hand	Thumb	Eye	Foot
1	Right	Left	Right	Right
2	Right	Left	Right	Right
3	Right	Right	Right	Right
4	Right	Left	Left	Right
5	Right	Right	Left	Right
6	Right	Left	Right	Right
7	Right	Left	Left	Right
8	Right	Right	Right	Right
9	Right	Left	Right	Right
10	Left	Right	Left	Left
11	Right	Left	Right	Right
12	Right	Right	Left	Right
13	Left	Left	Right	Right
14	Left	Right	Left	Right
15	Right	Left	Left	Right
16	Right	Left	Right	Right
17	Right	Left	Right	Left
18	Right	Left	Right	Right
19	Right	Left	Right	Right
20	Right	Left	Left	Right
21	Right	Right	Right	Right
22	Right	Right	Right	Left
23	Right	Left	Right	Right
24	Right	Left	Left	Right
25	Right	Right	Right	Right
26	Right	Left	Right	Right
27	Right	Left	Right	Right
28	Left	Left	Left	Left
29	Right	Left	Right	Right
30	Right	Left	Right	Right
31	Right	Right	Right	Right
32	Right	Left	Left	Right
33	Right	Right	Left	Right
34	Left	Left	Left	Right
35	Left	Left	Right	Right
36	Right	Left	Left	Right
37	Right	Right	Right	Right
38	Right	Left	Right	Right
39	Right	Left	Right	Right
40	Right	Right	Left	Right
41	Right	Right	Right	Right
42	Right	Left	Right	Right
43	Right	Left	Right	Right
44	Right	Left	Right	Right
45	Right	Left	Right	Right
46	Right	Left	Left	Right
47	Right	Right	Right	Right
48	Right	Left	Left	Right
49	Right	Right	Left	Right
50	Right	Left	Right	Right

Data from "Right-Handed and Left-Footed? How Andrea learned to question the facts." by Thomas R. Lord, *Science and Children*, October 1986

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Resource Material

The Ambidextrous Spreadsheet

The capabilities that a spreadsheet offers for this investigation include the following:

◆ Data can be entered without knowing in advance how much data there will be since it is always possible to add more columns if additional tests are designed and to insert more rows at the bottom if additional subjects are tested.

◆ Printing out the spreadsheet provides a neat and organized table to use with any writeup of the investigation.

◆ Using the calculational abilities of the computer and the built in functions of the spreadsheet facilitates data analysis. Not only is it easier, but the ease means that one is willing to try alternative ways of looking at the data. With the pencil and paper analysis, there is a tendency to do it one way and that is it.

In addition to these investigation specific advantages, there are additional reasons for using the spreadsheet in investigations. These include:

◆ Computer literacy is now a recognized educational goal, and this is best taught within the context of other courses rather than in a separate computer literacy course.

◆ Setting up a spreadsheet requires thinking about the data and about how to analyze the data. This becomes a way that helps one to focus on this process.

◆ A spreadsheet offers an interesting alternative notation for variables that can be a bridge to the infamous "x" of algebra. In a spreadsheet a variable is named by its cell address, and the address can be accessed by pointing with the cursor to the cell. In this way writing a formula is similar to pointing and saying multiply this by that.

Data analysis includes finding how many people were right, left and ambidextrous for each test. To calculate these sums, the computer needs numerical values. In Excel, which is the spreadsheet example shown here, the data is entered as text characters, not numbers. Excel can then find the sum for each character. Here is the formula for Sum R:

=Sum(B5:B23="R",1,0) and then hold down the Apple command key and press Return. This formula says for each cell to assign a value of 1 if the character is R, otherwise a value of 0. Once formulas are entered in column B, they can be copied across for the other columns.

For spreadsheets that do not have this command, data can be entered numerically, such as 1 for Right, -1 for Left and 0 for Ambidextrous.

	A	B	C	D	E
1	RIGHT LEFT OR AMBIDEXTROUS - Data from a workshop				
2					
3	Person	Eye	Hand	Foot	Thumb
4					
5	1	R	A	R	R
6	2	R	R	R	L
7	3	L	R	R	R
8	4	R	R	R	L
9	5	R	R	R	L
10	6	L	R	R	L
11	7	R	R	R	L
12	8	R	R	R	L
13	9	R	R	R	L
14	10	L	R	R	R
15	11	R	R	R	L
16	12	R	R	R	R
17	13	R	R	R	L
18	14	L	R	R	L
19	15	R	R	R	L
20	16	R	L	L	L
21	17	L	L	R	L
22	18	L	L	R	R
23	19	L	R	A	L
24					
25	Sum R	12	15	17	5
26	Sum L	7	3	1	14

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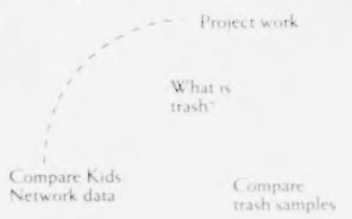
Trash

Overview



Materials

Trash samples — one per station
Rubber gloves
Aprons
Newspapers to protect tabletops, desks, floors
Extra plastic garbage bags or other containers for holding trash
Notebooks/paper, pencils, for recording data
Calculators
Small and large scales
Conversion coefficients (ounces to pounds, nonmetric to metric)
Telecommunications software and one station for every 2 to 4 participants
Activity Sheet

Preparation

Telecommunications

Provide participants with a timeline for online communications. (For example, see the *Trash* Activity Sheet.)

Set up the telecommunications stations. Send a welcome message for participants to pick up and reply to when they first sign on to the telecommunications network.

Trash

For an intensive 1- or 2-week workshop: Provide each team with a full bag of trash. Each sample should be unique, that is, from a different kitchen. The more that participants know about their sample, the richer their discussion about it can be, so it is best to have participants bring in their own home or classroom trash.

For a 1-day session which has been preceded by a prior session at some earlier date: Have participants collect and bring in one day's worth of classroom trash, or a sample bag of lunchroom trash.

For collection and safety tips, see the next page.

Purpose and Rationale

This activity will give participants the experience of collaborating over a telecommunications network; provide them with an opportunity to analyze data; and encourage them to think about the different educational goals served by different types of telecommunication networks.

The hands-on portion of *Trash* is modeled after several activities in the NGS Kids Network's *Too Much Trash?* unit. Participants explore the issues involved in defining a problem, organizing or categorizing data, quantifying the data and then analyzing it.

Because defining a problem and arriving at an organizational strategy collaboratively are more complex than simply gathering and sorting data according to a predefined plan, we emphasize them here. If participants take this activity back to their classrooms, they may use telecommunications to coordinate their students' data collection; for this reason, we have integrated telecommunications into participants' experience of the activity. It is also important for participants to spend time analyzing the data collected. Data analysis is often neglected in telecommunications-mediated activities.

Not all technologies are equally well suited to support all learning objectives. We have included an exercise in which participants compare two different versions of the activity because it is important for teachers to match the learning objectives and educational goals that they have for students to their choice of telecommunication network service.

Our second aim is to model one example of how more open-ended offline activities can be used to enhance or extend a prescriptive telecommunications curriculum.

Synopsis

Participants are introduced to telecommunications software and given an overview of the *Trash* activity, then discuss the question: *Do different kitchens generate different kinds of trash?*

In their groups, participants develop a definition of trash; they then get online and come to a consensus about a definition as a large group.

Once all groups have agreed upon how to organize their samples in order to compare their data, participants sort, organize and define trash samples, share their data online, and look for patterns across all samples. Reflection focuses on their own learning.

Finally, participants compare the tasks and skills emphasized by NGS Kids Network's approach to those supported by the more open-ended approach that they have just experienced. Time: 5–6 hours, preferably in the same day.

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Opening Activity

What is trash?

Introduce the activity and provide an overview of what will happen. Participants will aim to reach consensus on answers to the questions: *What is trash? How different is the trash generated by different kitchens (or schools)? What are the implications of these differences?*

Introduce the telecommunications network and demonstrate the software you will be using for network communications during the session.

Divide the participants into teams and assign them to their stations. Ask that everyone in the group "get their hands on" both the computer (e.g., the telecommunications software) and the trash samples.

Participants online: Participants should spend a few minutes familiarizing themselves with the software.

Participants offline: The teams brainstorm and discuss their ideas about the answer to the question *What is trash?* Participants usually discover that the answer is more complex than it first appeared to be.

Participants online: Once a team has agreed upon a definition of "trash," they communicate it to the other teams. Teams must jointly arrive at a consensus about this definition before they proceed to the next phase of the activity.

Participants offline: Participants may find it helpful to sort through their trash sample in a preliminary way at this point. The trash samples provided are not likely to contain examples of all possible types of trash. While the goal of the activity is to compare trash samples, participants need not confine their definition of trash to what is included in their samples.

You might determine if a consensus has been reached by checking in on each team and asking, "What definition of trash has everyone agreed upon?"

Collection and Safety Tips:

It is very important that participants handle and sort through actual trash.

- Collect liquid and food in leakproof containers (with lids) separately from other types of waste.
- Remember to weigh the empty collection containers so that this weight can be subtracted from the total weight of waste and container.
- Communicate with custodial staff to make sure the trash you collect is not disposed of.

Warn participants to use caution as they sort their samples. Some common sense precautions are:

- Be careful when handling cans, lids and broken glass.
- Wear gloves or plastic bags on hands when handling trash.
- Do not eat anything in the trash samples.
- Do not collect bathroom or medical waste.

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Exploration

How different is the trash generated by different kitchens?

Participants offline/online: Teams must decide how they will answer this question; that is, how they will compare samples. What kinds of categories will they organize their trash into, and how will they quantify their samples? Teams quantify their data, organize it into the agreed-upon categories and communicate this to the other teams.

Arriving at a consensus about how to sort the trash samples may be difficult, particularly if the samples are very different. You may need to push for consensus here, as before, asking, "How have you agreed to sort your trash samples?" One team may take the lead in bringing the others to a consensus.

Participants offline: Once all teams have sent their data, they should examine all data for comparisons and patterns. *How different is the trash generated by different kitchens?* Teams should send questions to other teams if they need more information about samples.

Taking time to analyze the data is an extremely important part of any data collection activity and one which can be difficult to do. Because this process will take place offline if the activity is transferred to the classroom, and because it would be difficult and time-consuming to conduct over the network, data analysis should take place offline in teams. Questions you might ask of each team are:

What patterns do you see in the data?

What do you know, and what can you say about it?

What questions do you have about the data?

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If possible, review the NGS Kids Network's Too Much Trash? *unit before this discussion so that you can answer participants' questions about it if necessary. NGS Kids Network uses "weight of the trash generated per student" in each of six predefined categories (*NGS Kids Network Too Much Trash? *Teacher Manual, p. 24, p. 37-38). These materials also cover unit conversion and estimation.*

Synthesis

Reconvene participants for whole-group discussion. Distribute sample data gathered by students during a session of the NGS Kids Network's *Too Much Trash?* unit, and a copy of NGS Kids Network's data collection sheet. (See the Activity Sheet.) Compare the NGS Kids Network data to the data just collected by participants.

It is likely that participants will have organized their trash into somewhat different categories than the NGS Kids Network unit uses. Discuss how the data might be compared. Questions which might help to provoke discussion:

What questions do you have about the NGS Kids Network data? About the way it is represented?

How does the Kids Network data compare to our data? Can we make a meaningful comparison? Is additional information needed about either one of the data sets?

Continue in whole-group discussion. First ask participants to reflect upon the content of the activity and on their own learning, for example:

What questions do you have now?

What would you investigate if you had the time?

Next, have participants consider the educational objectives supported by the two different approaches to an exploration of trash. Make two lists of learning objectives, one for the NGS Kids Network activity and the other for the activity that the participants have just completed. For instance, you might begin:

Kids Network "presorts" trash into categories and pre-defines how data will be quantified for comparison. Why? What are the advantages and disadvantages of this approach?

Other questions which might be considered:

What are the implications of this activity for actual classroom practice?

What are implementation issues and stumbling blocks?

What does telecommunication give you that you would not have otherwise had?

How does telecommunication change the role of the teacher? Of the student as learner?

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Sample lists of educational objectives supported by the two different approaches:

NGS Kids Network (Data Categories Predefined)

- *Efficient. Allows you to spend more time on the "scientific process."*
- *Structure is reassuring.*
- *Data collection is administered by NGS.*

Today's Activity (Data Categories Open)

- *Allows learners to define question.*
- *More flexible, allows for negotiating and consensus building within the classroom, with other classrooms.*
- *Provides more flexibility in choice of categories, more student choice.*

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Activity Sheet

Sample Trash Activity Schedule

10 minutes	Break into small groups. Read your LAN Welcome message. **Reply to all stations:** Your names and the name of your station.
25 minutes	Within your small group, discuss: *What is trash?* It may be helpful at this point to review your trash sample. *How might you organize your sample to compare it with those of other groups? How will you quantify your data to answer the question "how much?"*
30 minutes	**Network messages.** Exchange your definition of trash and categories with other groups. Negotiate a definition of trash that all groups can agree on. Decide how all groups will organize their trash sample data for comparison.
45 minutes	Quantify the data from your trash sample and prepare to communicate it. *What patterns do you notice in your sample? Can you explain these patterns? What additional information, if any, do you need?*
BREAK (Lunch)	
15 minutes	**Network messages.** Share your trash data via the LAN.
45 minutes	Analyze the collective trash data. *What patterns do you notice in the data from the entire group? How are they similar or different from the patterns of each of the small groups? Can you explain the patterns? What additional information, if any, do you need?*
45 minutes	Reconvene as a whole group. Consider a Kids Network data set, and compare your data to the Kids Network data. What *questions do you have now? What would you investigate if you had the time?*
30 minutes	Group discussion: *What are the implications of this activity for actual classroom practice? What does telecommunication give you that you would not have otherwise had?*

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Activity Sheet

NGS Kids Network
Data Collection Sheet

Activity Sheet # 4
Trash Per Student From Our Class
for use in Session 6 & 9

Name:

Number of students present Day 1: ☐ Number of students present Day 2: ☐

Copy in the first and third columns the weights you recorded on Activity Sheet 6 for Day 1 and Day 2. Use the number of students present on Day 1 to calculate weight per student for Day 1 collection. Use the number of students present on Day 2 to calculate weight per student for Day 2 collection.

Category	Day 1		Day 2	
	Weight in grams	Weight in grams per student	Weight in grams	Weight in grams per student
Food				
Glass				
Metal				
Paper				
Plastic				
Other				
Total weight		gram		gram

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Activity Sheet

NGS Kids Network Field Test Data

	Data Collected By Students NGS Kids Network's "Too Much Trash?" Unit			
Trash Types	Totals (grams per student)			
	BWILKINS.F	DRODDA.SOL	ELINDAHL.L	Average
Paper	72	84	78	78
Metal	3	1	2	2
Glass	0	0	0	0
Plastic	1	1	6	3
Food	284	45	21	117
Misc	1	0	18	6
TOTAL	361	131	125	206

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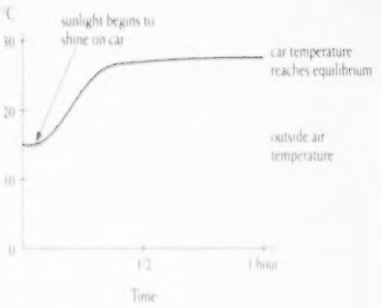
Hot Cars

Overview



Materials

100-watt desk lamps
Metal cans of various sizes
Cardboard
Thermometers with a range of at least 0-100° C (metal backed, digital or MBL)
Cellophane or stiff plastic, clear and colored
Rubber bands to fit around can mouths
Waxed paper
Scissors
Tape
Foil
Watch or clock
Graph paper
Chart paper (quadruled)
Telecommunications software and one station for every 2 to 4 participants
MBL temperature probe stations (optional)
Insulators: styrofoam*, clay, pebbles, sand, water, shredded newspaper*, pennies, bubble wrap*

* SAFETY NOTE: Do not use these materials for trials over 30 minutes long; the collector may heat up enough to melt or ignite the insulator.

Preparation

Provide participants with a timeline for telecommunications that clearly identifies what types of information they need to communicate on the network by when. (For example, see the *Hot Cars* Activity Sheet.)

Set up the telecommunications stations. Send a welcome message for participants to pick up and reply to when they first sign on to the telecommunications network.

Purpose and Rationale

The main objectives of this activity are: to engage participants in a question about materials which absorb and retain heat; to stimulate a substantive discussion around the phenomena of heat and light energy; and to model the use of telecommunications to support this kind of discussion.

This activity provides a forum in which participants may articulate their current concepts of heat and temperature — many people often do not distinguish between the two — and explore outstanding questions through hands-on work.

Telecommunications is used in this activity to model an online collaboration which does not require closely negotiated data collection procedures or a tightly synchronized experiment timeline. In addition, small group dialogues about heat and temperature are invariably enriched by subsequent online discussions with the larger group. In the workshop setting, these discussions could take place without telecommunications. However, network use is integrated here in order to provide participants with a glimpse of some of the benefits of having several, distant classrooms communicate with one another.

If participants are already familiar with MBL temperature probes, these may be used to collect and graph temperature data.

Synopsis

Working in small groups, participants will ask questions about and investigate materials that absorb and retain heat. At specific intervals during the day, they will communicate with the other groups via the telecommunications network in order to discuss the phenomena and coordinate activities. The goal at the end of the day is to design a prototype of the "best" heatkeeper on the basis of data collected from experiments run by all of the small groups.

After discussing, over the network, which factors influence a container's ability to "keep" heat, each group will conduct its own investigation of one of these factors. Different groups will investigate different factors. Groups will then share their data toward the goal of developing a prototype of a "best" heatkeeper.

Reflection focuses on participants' learning and how the technology enhanced or limited their learning. Time: This activity requires 5–6 hours to complete.

Resource Material

Page A.9-10

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Opening Activity

Introduce the *Hot Car Challenge* and provide an overview of what will happen.

Introduce the telecommunications network and demonstrate the software you will be using for network communications during the session.

Divide the participants into teams and assign them to their stations. Ask that everyone in the group "get their hands on" both the computer (e.g., the telecommunications software) and the materials.

The Hot Cars Challenge

- *Consider the example of a car in the summer time. The air inside typically gets much hotter than the air outside. Is there a limit to how hot the air inside can get? Does this happen to the same extent in the winter time?*
- *What factors affect how quickly the car or container heats up? What factors affect how long the car or container retains its heat? What makes one container a "better" heatkeeper than another? Make a list of the factors that affect how well a container is able to collect and keep heat. Predict what effect each will have.*

Exploration

Participants online: Participants spend a few minutes familiarizing themselves with the software.

Participants offline: Small groups discuss the *Hot Cars* challenge. In offline discussions, participants become more familiar with their own ideas about the phenomenon and develop their own questions about it.

Participants online: Groups exchange ideas about the *Hot Cars* challenge. Through online messages, all groups generate a comprehensive list of factors that seem relevant and predict how each factor affects the ability of a container to collect and/or retain heat. Groups negotiate which factor each will test.

Participants offline: They then design their test, collect the data and analyze it.

Participants online: Participants share test results over the network.

Participants offline: Each group then develops a prototype design on paper of a "best" heatkeeper. Remind participants that their designs should only be based on test data and should not include additional knowledge brought to the activity.

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Synthesis

When every group has designed its best heatkeeper, bring the groups back together. Groups share their designs, justifying their design choices.

What are the properties of a "good" heatkeeper?

What questions do you have now?

What would you investigate next if you had the time?

Then consider implementation, technology and student learning.

What are the implications of this activity for actual classroom practice?

What does telecommunications give you that you would not have had otherwise?

What are implementation issues and stumbling blocks?

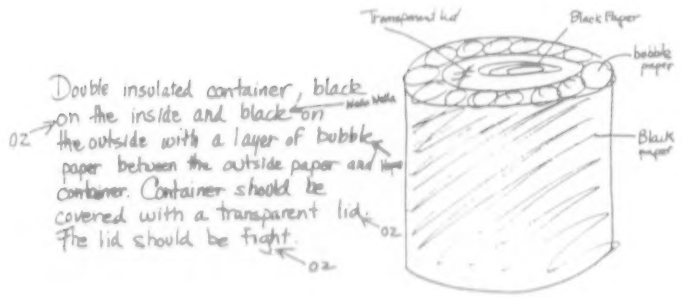
How does telecommunications change the role of the teacher? Of the student as learner?

Video — Workshop Case Study: In the video, teachers investigate the equilibrium temperature that their container reaches under a lamp. The case study might be used to consider the learning process. Discussion following the video might address:

How do the teachers articulate their understanding of the phenomenon? What role does this play in their learning process?

It may be helpful to describe or discuss the phase or phases of the learning process that the teachers move through.

How does telecommunications support the teachers' learning in this case study?


Transparent lid
Black Paper
bubble paper
Double insulated container, black on the inside and black on the outside with a layer of bubble paper between the outside paper and container. Container should be covered with a transparent lid. The lid should be tight.
Black paper
OZ
OZ
OZ

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Telecommunications from a Workshop

From: Walla Walla, WA Sat, Feb 6 10:11 AM

Subject: Hot Cars

Here are a few of our ideas about hot cars:

1. There is a limit on how hot the air in the car can be, it is determined by the amount of energy received from the sun.

2. The seasons are a factor in the amount of sun the car can absorb. Our belief is that the car will be hotter in the summer, generally, and that the difference between the temperature inside and outside the car will also be the greatest in the summer. This belief is based on the fact the head dissipates faster due to the differential of the outside and inside temperature.

From: Oz, KS Sat, Feb 6 10:11 AM

Subject: Reply to Hot Cars #1

Yes, there is a limit. But the question should be, "Is there a limit short of structural damage, that the air will reach before it stops." Our guess is that, all things being equal (i.e., tightness of the car, temperature inside versus outside, etc.) there is no limit to how hot it can get short of structural damage. We think that this is also true in winter.

From: Walla Walla, WA Sat, Feb 6 11:07 AM

Subject: Graph

We have graphed the temperature of the air in a sealed can as it received a constant amount of heat from a lamp over a 13-minute period. This confirmed that there is a limit determined when the amount of energy received equals the amount of heat lost. After the 10th minute the temperature stayed the same.

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Activity Sheet

Sample Hot Cars Activity Schedule

10 minutes	Break into small groups. Read your LAN Welcome message. **Reply to all stations**: Your names and the name of your station.
25 minutes	Discuss within your small group the *Hot Cars* challenge.

The Hot Cars Challenge

- *Consider the example of a car in the summer time. The air inside typically gets much hotter than the air outside. Is there a limit to how hot the air inside can get? Does this happen to the same extent in the winter time?*
- *What factors affect how quickly the car or container heats up? What factors affect how long the car or container retains its heat? What makes one container a "better" heatkeeper than another? Make a list of the factors that affect how well a container is able to collect and keep heat. Predict what effect each will have.*

30 minutes	**Network messages**. Exchange ideas about the Hot Cars challenge. Generate a list of factors that seem relevant. Negotiate which factor each group will test.
60 minutes	Collect data, graph as appropriate, and analyze.
BREAK (Lunch)	
30 minutes	**Network messages**. Share test results.
45 minutes	Imagine that you want to keep your model car or container as hot as possible. Design a "best" heatkeeper based on the collected test data from each group. This is a paper and pencil task. Your design should only be based on the test data and not include additional knowledge you undoubtedly have.
45 minutes	Reconvene as a whole group. Share designs, including the underlying reasoning. Discussion: Science, technology and learning.
30 minutes	Group discussion: *How do I implement this in my schools?*

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Overview

Project Work with Telecommunications

Materials

Materials provided for previous workshop activities

Additional materials as requested by participants and as available

Large paper and colored marking pens

At least one telecommunication station with access to a bulletin board service and to the ERIC online research service

Preparation

Telecommunications

Create a "crib sheet" that very simply describes

- how to log on to the long-distance network;
- how to post and receive messages on the bulletin board service; and
- how to conduct an ERIC search.

If possible, provide a list of valid ERIC search keywords.

Working With A Scientist Online

Prior to the workshop, arrange for one or more scientists to be online and replying to e-mail regularly (preferable a few times per day) during the 2 to 3 days during which participants will be working on the projects.

Purpose and Rationale

In this module, participants conduct an investigation of their own design that builds upon their exploration with one of the earlier activities (for example, Right, Left or Ambidextrous?, Trash, or Hot Cars). While telecommunications is supplemental to the participants' work here, they are required to use long-distance networking in at least two ways: (1) to expand their work in some way by posting a message — which might lead to a discussion, a collaboration or an expanded data collection effort; and (2) to augment their information or research about the topic under investigation. The goal is to provide participants with a practical experience in which telecommunication supports their own investigation and learning.

Synopsis

Working in small groups, participants choose a question and plan an investigation based on their experience with a previous activity. In addition to their investigation, they must

- *send a "message in a bottle," that is, post a question that might inform their exploration on an electronic bulletin board service;*
- *search an online database, such as ERIC, for information that may inform their investigation; and*
- *initiate a discussion related to their project work with a scientist online (optional).*

Participants plan their investigations. Time: Two hours.

Groups then carry out their own investigations. Time: Four hours.

Finally, groups compare experiences and reflect on their learning. Time: One–two hours.

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Opening Activity

Introduce long-distance networking. Demonstrate how to use an electronic bulletin board service. Provide tips for framing a message so that it is more likely to elicit a response.

Demonstrate ERIC or another research database that is broad enough to be potentially useful to investigations into the activities being investigated (e.g., *Trash, Hot Cars*).

Tips for Crafting a "Message in a Bottle"

- It's best if your entire message is no longer than a short paragraph which people can read and respond to while online.
- Briefly introduce yourself and explain your purpose.
- End your message with your question, clearly stated, and the date and time by which you need to receive responses.
- "Test" your message with participants in another group. Their feedback may help you clarify your message.
- Be aware that you may receive no responses. Your response rate is a function of many factors beyond your control, such as the volume of traffic on the BBS where you post your message and the network's audience, both of which may vary over the course of the year. (For instance, a regional network for teachers and students is likely to be less active in the summer time than during the school year.)

Exploration

Participants offline: Choose a question to investigate. Brainstorm as a large group, or have participants organize themselves by the activity/phenomenon they would like to explore further. Groups should come to a consensus regarding the question they would like to investigate.

Participants offline and online: Design and execute investigations. Small groups proceed with their investigations. There will be several feedback cycles as participants adjust their designs and analyze investigation results. During their explorations, participants should consider data from the following sources:

- *their own investigation,*
- *replies, if any, to the question(s) they post on an electronic bulletin board service,*
- *results from their external database search (ERIC), and*
- *their online discussion with a scientist (optional).*

Participants offline: Prepare summary presentations. Participant summary presentations should include

- *a description of their findings from all data sources,*
- *their new and/or unanswered questions and*
- *a discussion of their learning process.*

Each group makes a presentation to the whole group, sharing what they did, what they found out and what sources they used for their data.

Synthesis

Focus on participants' own learning.

What can you say about your learning process?

How did project work support your learning?

What did telecommunication add to your investigation that you would not have had otherwise?

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Extract of Sample ERIC Search

Keywords: Heat, Solar Energy

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AN: EJ442006
AU: Adney, -Kenneth-J.
TI: If the Sun Were a Light Bulb.
PY: 1991
JN: Physics-Teacher; v29 n2 p96-97 Feb 1991
AV: UMI
:
:

21 of 246

AN: EJ420912
TI: Technology Learning Activities. Design Brief--Measuring Inaccessible Distances. Alternative Energy Sources: Designing a Wind Powered Generator. Alternative Energy Sources: Designing a Hot Dog Heater Using Solar Energy.
PY: 1991
JN: Technology-Teacher; v50 n5 p5-8 Feb 1991
AV: UMI
:
:

23 of 246

AN EJ420578
AU: Garstang, -R.-H.
TI: How Hot Does Your Parked Car Become?
PY: 1991
JN: Physics-Teacher; v29 n1 p58 Jan 1991

Extract of Sample ERIC Search

Keyword: Trash

1 of 50

AN: EJ449366
AU: Ramondetta, -June
TI: Using Computers. Learning from Lunchroom **Trash**
PY: 1992
JN: Learning; v20 n8 p59 Apr-May 1992
AV: UMI
AB: Elementary teachers can help students consider how much **trash** they create by analyzing lunchroom waste. Students research the problem, brainstorm lists of items thrown away, and monitor the cafeteria, counting items and collecting data. They enter information into a spreadsheet which the class examines to search for alternatives. (SM)
:
:

3 of 50

AN: ED347077
TI: Let's Waste Less Waste. Operation Waste Watch: The New Three Rs for Elementary School. Grade 4. [Second Edition.]
CS: Virginia State Dept. of Waste Management, Richmond. Div. of Litter & Recycling.
PY: [1990]
NT: 19 p.; For other environmental education curriculum guides, see SE 052 789-795. For the first edition, see ED 325 318.

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Activity Sheet

How to access and use ERIC:

We recommend ERIC for this unit because it is the world's largest database of education literature and includes materials from a wide range of public and private sources. At the central core of ERIC are two indexes, updated monthly: The Current Index to Journals in Education (CIJE) for journal articles and Resources in Education (RIE) for documents, such as papers presented at conferences, which are not commercially published. With the appropriate access, teachers can search the ERIC database for the topic(s) of their choice and download abstracts of the articles located by their search. Articles cited in CIJE are not provided in full text by ERIC; users may find copies at libraries or order copies from private reprint services. RIE documents can be read at university libraries that hold the ERIC document microfiche collection, or copies may be ordered from the ERIC Document Reproduction Service.

Access to ERIC is available via:

- *Two commercial vendors: DIALOG Information Services and BRS Information Technologies. These services offer the most powerful search capabilities, but their search software is the most complex to learn. Costs include: membership fee, connect-time charges and a fee for each citation downloaded.*
- *CompuServe offers access to the ERIC database through its easy-to-use IQuest search system. In addition to CompuServe's connect-time costs, a per-search fee is assessed.*
- *GTE Education Services, an online service designed especially for teachers and school administrators, provides access to the latest three years of ERIC, as well as other information resources. Costs are based on the number of minutes connected.*
- *Libraries with the Online Computer Library Center, Inc., (OCLC) offer access to ERIC through OCLC's FirstSearch service. Fees and access policies are determined by the host library.*
- *Internet Access: If you have an education question, use e-mail to askeric@ericir.syr.edu. If you have Gopher of FTP, connect to ericir.syr.edu. If you have Mosaic, Lynx, or another client, open the URL and connect to http://eryx.syr.edu. Telnet to: ericir.syr.edu and type "gopher" at the login prompt.*

For more information, contact ACCESS ERIC at 1-800-538-ERIC. ACCESS ERIC answers questions about using ERIC and serves as a central dissemination point for ERIC Clearinghouse products.

Information on ERIC has been abstracted from a September 1992 digest prepared by Nancy Preston of the ERIC Clearinghouse on Information Resources, Syracuse University, Syracuse, NY.

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Activity Sheet

Tips for Crafting a "Message in a Bottle"

- *It's best if your entire message is no longer than a short paragraph that people can read and respond to while online.*
- *Briefly introduce yourself and explain your purpose.*
- *End your message with your question, clearly stated, and the date and time by which you need to receive responses.*
- *"Test" your message with participants in another group. Their feedback may help you clarify your message.*
- *Be aware that you may receive no responses. Your response rate is a function of many factors beyond your control, such as the volume of traffic on the BBS where you post your message and the network's audience, both of which may vary over the course of the year. (For instance, a regional network for teachers and students is likely to be less active in the summertime than during the school year.)*

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Overview

Opening up an Activity

Materials

Two different prescriptive activity sheets (see Preparation)

Refer to materials lists for "Sundial" and "Volumes" activity sheets; participants may also require additional materials.

Preparation

We have included two activity worksheets; these activities are related to the *Hot Cars* and *Trash* modules. If you prefer to use other activity sheets, look for typical student worksheets that are characterized by the following:

- exact and detailed instructions for carrying out the activity, with no accommodation for deviation from the directions;
- charts and tables for representing data gathered already provided, discouraging student use of their own representations;
- fill-in-the-blanks or narrowly guided questions, leading students to the "correct" answers.

Purpose and Rationale

The goal here is to enable teachers to revise prescriptive curricula in order to more effectively support student learning. There is also an opportunity for participants to consider when a prescriptive exercise may be necessary for a telecommunications activity, and how they might open up such an exercise for offline classroom implementation. This activity gives teachers an opportunity to be critical of a curricular piece in a context that models and supports a revision of the activity. This process may be used to carefully examine any activity.

Virtually all of what little curriculum exists for student telecommunications is highly prescriptive or directive. Implementing these curricula in a way that is more responsive to students can be a tremendous challenge: Not only is this difficult to do in and of itself, but also data sharing via telecommunications, as currently conceived in most existing materials, often requires a high level of coordination in order to ensure data integrity.

This activity is based on one designed by Wynne Harlen for the 1987 UNESCO International Seminar on Primary Science Teacher Training for Process-Based Learning.

Synopsis

In small groups, participants execute two different activities, "Sundial" and "Volumes," as described on the sheets provided them, then analyze what they have learned from the activities. Next, participants redesign the activities to emphasize process skill work but still focus on the core science concepts of the original activities. Once the activities have been redesigned, each "Sundial" group swaps its revision with a "Volumes" group. Participants execute the revised activities and assess what they have learned. Groups that swapped activities come together to give each other feedback on the revised activities; then the whole group convenes to analyze the revised activities and discuss the process of opening up an activity. Time: 4–6 hours.

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Opening up an Activity

Opening Activity

In small groups, teachers will execute the activity exactly as detailed on the student activity sheet provided. In contrast to other workshop sessions in which they have been encouraged to follow their own questions and conduct their own explorations, it is important that, in this case, they follow the instructions provided exactly. After they have conducted the activity, teams will consider what types of learning it supported.

Exploration

The group is divided into teams of three to five participants each. There must be an even number of teams. Later, each team that has worked with the "Sundial" activity sheet will swap its revised sheet with a team that has worked with the "Volumes" sheet.

Teams execute the activity sheet and analyze their learning.

As each group completes the prescribed activity, present it with this task: *How can the activity be restructured to better support process-based learning and motivate students to take responsibility for their own learning?* It may help to consider the following.

What is the lesson trying to accomplish? What is the concept at its core? Focus on the concept. Feel free to drop the activity entirely and develop another that better supports process-based learning around this concept.

Re-frame the activity title as a driving question.

Generate a list of process-based science skills.

How will you use the process of science to support student learning in the activity?

What choices will you leave open to students?

What opportunities will you provide for students to reflect upon their own learning?

Swap and execute "opened" activity sheets: After they have opened up the activity, teams swap and execute revised activity sheets. Each "Sundial" team swaps its revised sheet with its "Volumes" team-pair. In this way, teachers who have been working on revising the "Sundial" activity have neither seen nor analyzed the original "Volumes" activity sheet and vice versa. They will not be able to compare the revised sheet with the original at this point. Teams execute the revised activity sheets, then answer the question:

What types of learning did this activity support?

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Paired groups discuss revised activity sheets: Teams that swapped activity sheets come together and discuss whether or not the revised activities provided greater opportunity for process-based learning and student responsibility for their own learning. Reviewers should provide evidence from their experience of doing the activities.

Synthesis

Large group plenary session: Discuss the revised "Sundial" activity sheets; then the revised "Volumes" activity sheets. *Do the revisions improve upon the originals?* Record the evidence. Discuss how teachers might transfer this workshop experience to other activities that they use specifically, and to the curriculum materials they work with in general.

Appropriate use: Distribute NGS Kids Network's "Activity Sheet 5, Session 4, Building A Solar Collector," which provides prescriptive design instructions for a solar collector. Discuss as a group:

When is this level of direction/prescription important?

How might you implement it in your classroom to allow for some process skill work?

What are the implications for telecommunication activities in general?

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Activity Sheet

Opening Up An Activity
Volume versus Weight

Definitions

Weight: a measure of the heaviness of an object; specifically, the force due to gravity on an object.

Mass: the quantity of matter in an object. More specifically, it is the measurement of the inertia or sluggishness that an object exhibits in response to any effort made to start it, stop it or change in any way its state of motion.

Volume: the size or extent of a three-dimensional object or region of space.

Density: a measure of the compactness of matter, of how much mass is squeezed into a given space. It is the amount of matter (mass) per unit volume.

Materials

Jelly beans, shelled peanuts, raisins, dried beans, sand

Metric equal arm balance scale and weights

Plastic or paper cups for measuring

Directions

- Does one cup of everything weigh the same?
- Fill cups with each material.
- Rate the materials from lightest (#1) to heaviest (#5). Record your ratings in Part 1 of the worksheet below.
- Estimate how much 1 cup of each material will weigh in grams, and record your estimates in the "Estimate" column of Part 2 of the worksheet below.
- Weigh each material and record its actual weight.
- Answer the questions at the end of the worksheet.

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Activity Sheet

Worksheet—Part 1

Items	Guess	Actual
Jelly Beans		
Raisins		
Dried Beans		
Shelled Peanuts		
Sand		

Worksheet—Part 2

Substance (use a measured scoop)	Estimate weight (g)	Actual weight (g)	Difference (E – A)
Jelly Beans			
Raisins			
Dried Beans			
Shelled Peanuts			
Sand			

Total Difference _____ ÷ 5 = _____ Average Difference

Questions

- *Does one cup of everything weigh the same?*
- *Why didn't they all weigh the same?*
- *Relate the terms mass, density, weight and volume to this investigation.*

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Activity Sheet

Opening Up An Activity

Materials

Flashlight

12-inch ruler

Modeling clay

Large piece of paper

Directions

- *How does moving the position of the flashlight change the shadow cast by the ruler?*
- *Place the paper on a flat surface, such as a desk or table.*
- *Roll the clay in a ball and press it into the center of the paper.*
- *Press the ruler into the clay so that the ruler stands straight up, that is, at a 90° angle to the table.*
- *Turn the flashlight on and hold it in the position shown in Figure 1. On the paper under the clay, draw the shadow you see.*
- *Repeat for figures 2, 3 and 4.*
- *Experiment by holding the flashlight in other positions. What happens?*

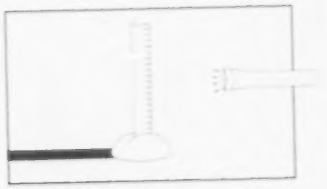

Figure 1

Figure 2

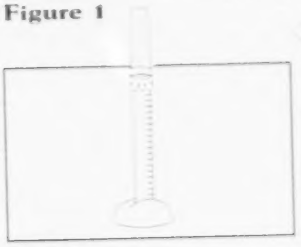

Figure 3

Figure 4

Questions

- *How does moving the position of the flashlight change the shadow cast by the ruler?*
- *Where was the flashlight when the shadow was longest? Where was it when the shadow was shortest?*
- *If the flashlight position in Figure 1 represents the early morning sun, what time of day is represented in each of the other figures?*

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Overview

Designing a Project for the Classroom

Purpose and Rationale

The goal of this and the next activity is to integrate what participants have done in your workshop with what they will do in their classrooms. First, participants need the opportunity to design a specific project for their students. Rather than trying to modify their whole program, teachers can begin by designing a short sequence of learning experiences using the project-based science model and trying it out in their classrooms.

Long-term change is best accomplished when teachers have opportunity to try out small changes in their actual practice, and then return to a group of their peers to reflect on their experiences. In this context, we suggest you encourage your participants to test run their projects in the classroom and then report back in a follow-up meeting.

When your participants are ready to consider broader issues of implementation, they can work through the activity *Integrating Projects into the Curriculum*.

Materials

Paper and pens
Resource books (optional)
List of suggested guidelines
Examples of project-based science instructional models

Synopsis

In these activities, participants use their reflections as the foundation for designing a classroom project. They draw from their experiences the important elements they want to transfer to their classrooms, design a single-topic project and share project designs. Time: 1/2 day.

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Designing a Project for the Classroom

Opening Activity

To help the participants to incorporate the workshop ideas into their practice, provide time (15 to 30 minutes) for them to consider: *What is important for science learning?* Encourage them to reflect on their own about the workshop experience and its implications for their classrooms. Suggest that the participants record their thoughts about the following:

What are the important features of project-based science learning? From your workshop and other experiences, pick out the elements you feel are most critical. Include thoughts about topics, structure, process, project models, support strategies, and assessment. What role can technology play?

In small groups, have the participants compare ideas in preparation for designing a project for use in their own classrooms.

Exploration

Invite the participants to choose a science topic (e.g., human physiology, light, motion, heating and cooling, environments, plants, energy transfer) that they will teach in the next few months and to work through the suggested guidelines.

Suggested Guidelines for Developing a Project

- Choose a topic that you will be working with in the classroom.
- Work from what you want to accomplish. What understandings will you try to help your students build?
- Choose an overriding question.
- Generate a list of activities that could help your students to further their understanding of the overriding question.
- Select several activities that will effectively address the issue.
- Identify an organizing question for each of these activities.
- Decide how you will use the microcomputer-based lab to support children's learning.

It might be helpful to begin the process by displaying and discussing one or two examples of how project work grew out of the workshop experiences, e.g., *How Does Light Behave?* and *Hot Cars*.

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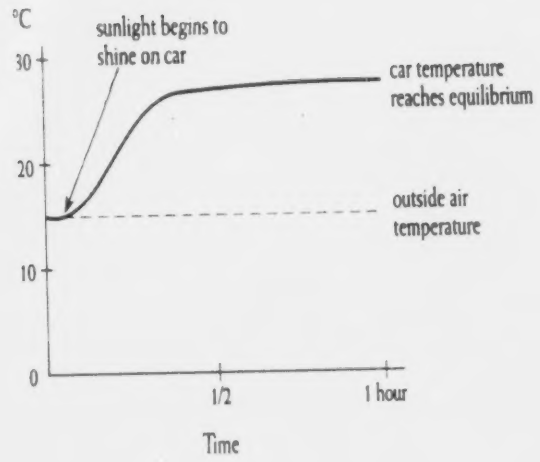
Example of a Project



During the development process, encourage the participants to help each other with ideas. There is a level of unpredictability in this experience. Participants will meet with different levels of success. However, addressing individual teacher needs is important for having ideas reach the classroom. Don't expect participants to leave with a project fully in place. Some may only have the beginning frame for a project. Let the participants know that this may be hard work.

Synthesis

Participants meet in an all-group session, present "work to date" and receive input from others. If you are planning a follow-up workshop, you might ask the participants to "test run" the project in their classrooms and to share the results of their experiences at the follow-up meeting.

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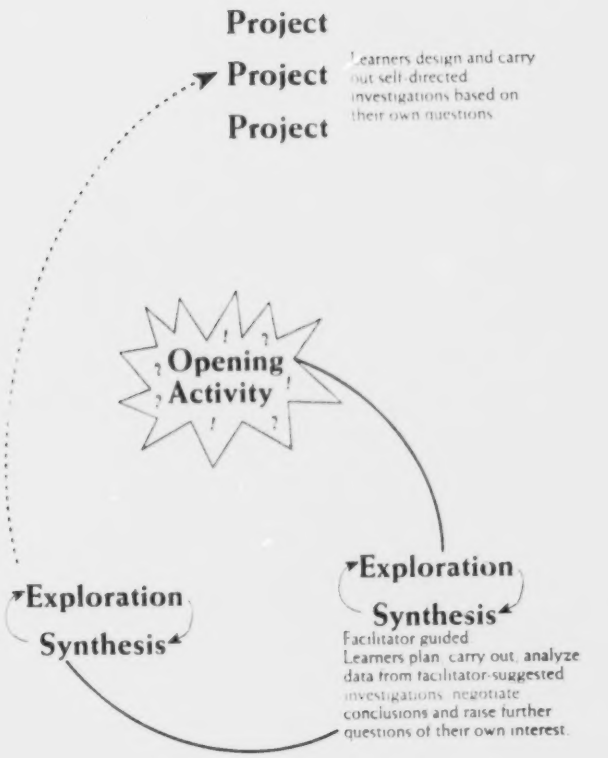
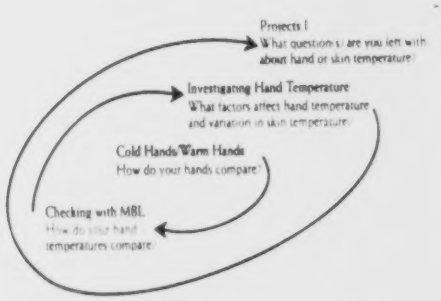
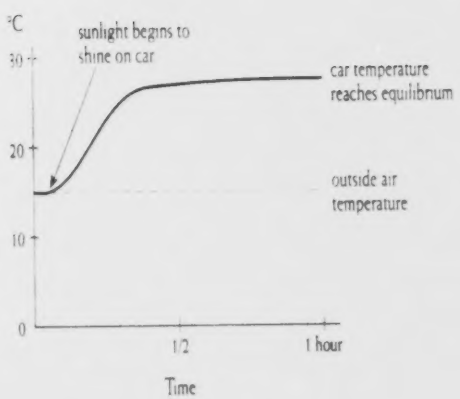
The Hands-On Elementary Science Instructional Models of Project-Based Science




Projects I
What questions are you left with about hand or skin temperature?
Investigating Hand Temperature
What factors affect hand temperature and variation in skin temperature?
Cold Hands/Warm Hands
How do your hands compare?
Checking with MBL
How do your hand temperatures compare?

Project work evolves from facilitator-initiated to participant-initiated. Project work may or may not be collaborative. Technology is used as a tool to support the learner as appropriate. In project-based science, both content and process are integral.



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Overview

Integrating Projects Into the Curriculum

Materials

Chart paper and markers for each group

Activity sheet

Purpose and Rationale

We want to build bridges from the activities described in these workshop materials both up to the general objectives of the science curriculum for elementary grades four to six and down to specific curriculum topics. Assuming teachers want to change in the directions indicated during the workshop, it is not enough just to want to change. Help is required to guide teachers as to how to do this.

One important principle underlying this activity is that project work should NOT be thought of as extra stuff to be added to what is covered by the regular curriculum, but rather as a way of doing these pieces of the curriculum using a project approach.

The first hurdle to emerge in discussions about integrating projects into the curriculum is often, "Oh, but we can't spend so much time on just one topic." The attempt here is to show that each project has within it aspects of several topics, and that several of the project activities visit the same topic from different points of view.

That leads us to a second important principle: there is a need to revisit the same topic from several different points of view in order to allow students to develop a good understanding of that topic. Further, if the topic is judiciously selected, a good understanding of a well-chosen topic can become a window through which students can view other topics that are tackled subsequently.

An illustration of this idea should help. Within the three workshops described in this manual, a theme that is revisited several times is heating and cooling: for example, *Cooling Works*, *Hot Cars* and *Representing Change: A Melting Popsicle*.

Synopsis

Participants take project ideas that come from these workshops and develop ways to integrate them into their classrooms. Time: One-half day / three hours.

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Integrating Projects Into the Curriculum

Opening Activity

Ask participants to take project ideas that come from these workshops and develop ways to integrate them into their classrooms to teach topics they either want to teach or are required to teach. For example, a rich activity could be developed around the topic of heating and cooling. Integration should total six weeks or more of the full year course.

Organize teacher groups by subject interest. In this way, teachers will be grouped across the three grade levels, which means there is the potential for differing ideas and contributions. It also means that upon sharing with other groups, there will be a chance to compare plans and note common themes.

Form small groups to tackle the question: *How will I integrate what I have learned in this workshop into my classroom activities?* Have the participants keep notes of their ideas for use when they construct a report for later sharing.

Exploration

Assemble the whole group together again to share and critique each group's plan.

One crucial question to address is whether the process of integrating into the curriculum has maintained the integrity of the project idea as a powerful learning vehicle for students.

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Synthesis

Encourage teachers to devise a plan to continue working together after they leave the workshop, so that they can continue to share progress on the implementation of their plans, and provide support for each other.

You and the group will need to organize an ongoing structure to support this, so as to keep the networking within the group active after the end of the workshop. This could happen at meetings if the teachers are geographically close, or over an e-mail network if participants have access to one.

Possible Ways of Tackling the Problem of Integrating the Workshop Activities into the Curriculum

- *Take a workshop activity and see how many concepts this activity forms a springboard to.*
- *Take a concept or a group of concepts and see which workshop activities support understanding of those concepts.*

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Resource Material

Classroom Implementation Ideas

Watching the Drops

The following are questions generated by third/fourth grade students when they observed the drops cylinder. What conceptual understanding might their questions lead to?

1. *How long does it take for all the drops to fall?*
2. *What are the droplets made of?*
3. *What are the "air" bubbles made of?*
4. *How do the drops stay as drops?*
5. *How fast do the drops fall?*
6. *Do they take different times?*
7. *Is there water and oil?*
8. *Why are the drops all the same size?*
9. *Why is the drops' rate so slow?*
10. *Where do they come from?*
11. *Why is it not just a steady stream?*
12. *How many drops are there in there?*
13. *Why are the drops always the same?*
14. *How many ingredients are there in the blue drops?*
15. *Is there any air inside?*
16. *Why don't the drops mix with the clear liquid?*
17. *Are the balls a liquid, a solid, or a bubble?*
18. *Why are the first drops bigger and the later ones smaller?*
19. *Where do the drops go?*
20. *Why do the drops stop at the bottom?*

Classroom Extensions

1. *Drops go down a hole or drain at the bottom of the drops cylinder, but when it is turned over the drops only come out of the spigot and none come back out the drain. Students were asked to draw a design for what could be under the opaque caps that would cause this behavior.*
2. *One boy shared with the class an experiment he and his older brother had done at home. Using cooking oil, water, food coloring and an eye dropper, he released blue water drops into a beaker of oil. The drops fell slowly in the oil, without losing their shape or color. He said the speed of the drops falling was different for different cooking oils.*

Cooling Works

The following are some of the implementation ideas teachers have either suggested or tried:

- *For the Cooling Challenge, let the students decide on what constraints to impose on materials and initial conditions, e.g., whether or not to include materials such as styrofoam. In one instance, students stated that the quantity of water could be either one or two cups and that the initial temperature had to be greater than 40°C.*
- *Set as a student challenge how to get the two containers to start at the same initial temperature.*
- *Ask students to design experiments that focus on the relative importance of single variables:*
  - *material the container is made of*
  - *size of the container*
  - *shape of the container*
  - *volume of the water*

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Activity Sheet

Integrating into the Curriculum

We want to build bridges from the activities described in these workshop materials both up to the general objectives of the science curriculum for elementary grades four to six and down to specific curriculum topics. One important principle underlying this activity is that project work should NOT be thought of as extra "stuff" to be added to what is covered by the regular curriculum, but rather as a suggested way of doing these pieces of the curriculum using a project approach.

You are asked to form small groups to tackle the question: *How will I integrate what I have learned in this workshop into my classroom activities?*

Integration should total six weeks or more of the full year course.

While thinking about these issues, keep notes of your ideas for use when you construct the report on your plans you will make to the other groups.

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Assessment

Overview

Purpose and Rationale

Curriculum, teaching strategy and assessment are intimately linked. One cannot teach science using a project-based curriculum while continuing to assess students with traditional paper and pencil tests. The goal of this activity is to introduce participants to alternative student assessment procedures that match a project-based science approach.

Synopsis

In this activity, participants will develop an assessment framework for use with the project plan developed in the previous activities: *Integrating Into the Curriculum*, and *Designing a Project*. Time: Three hours.

Materials

Participant activity plan from *Integrating Into the Curriculum*

Chart paper and markers

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Opening Activity

Invite each participant to talk for a few minutes each about the assessment procedures they are currently using to gauge their students' progress. Take notes during this reporting for use when you come to divide up the group later.

Then lead a discussion on the themes that have emerged during the above accounts. Provide guidance for this by introducing some of the issues:

- *If one goal of science curricula is to have students develop and pursue their own research questions, formulate and test their hypotheses and analyze and interpret their data, then assessment must likewise concentrate on the development of these skills.*
- *Two broad categories of information should be sought by teachers on an ongoing basis. The first is the scientific, conceptual understandings that students have and the way these understandings change over time. The second category that is essential to assess is the scientific process that students engage in to deepen their understanding of a phenomenon.*

Exploration

For this phase, have participants divide into small groups to brainstorm alternative assessment strategies. Two possibilities for how they do this are to

1. *join colleagues who worked together on the previous activity, or*
2. *construct groups that contain a mix of people using different assessment strategies.*

Ask the participants to consider

- *what aspects of children's understanding they will choose to assess,*
- *how they will gather data about these understandings during the activity and*
- *how they will use their findings.*

Explain that the outcome of this discussion should be a specific assessment framework that the group will develop in relation to one of the activity plans developed in the previous section on classroom integration of project work.

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Synthesis

Have the participants present their plans to the whole group.

Round up this phase of the activity by developing a synthesis of the points raised by each plan. You can use the following as a guide to help focus on issues that may not have been raised by the participants themselves.

What are we looking for in our assessment of project-based work? Assessment of project-based work cannot take the form of an end of unit test but rather needs to be ongoing in nature. There are multiple ways to assess project-based instruction. These include group discussion, individual interviews, careful observation of project work, review of artifacts, drawings written work, and oral presentations. Optimally assessment should be embedded into the activities.

Assessing the process of how a student obtained his or her results is crucial in informing the teacher about the guidance that must be provided and the direction that instruction should take. In particular, we need to be concerned with the following:

Posing a Researchable Question: To what extent are students able to consider a scientific phenomenon, generate questions that are interesting to them and identify a researchable question?

Formulating a Hypothesis: To what extent are students able to suggest some predicted outcomes and communicate their reasons for making their predictions?

Developing a Plan: To what extent are students able to plan the steps required to carry out an investigation, identify variables that may affect the outcome of their investigation and consider the materials and resources that they will need to carry out an investigation?

Interacting With Technology: To what extent are students able to utilize technology as a tool to collect their data, identify real data from artifact and communicate their ideas to others?

Analyzing Data: To what extent are students able to organize the data that they collect, recognize patterns or trends in their data sets and represent their conclusions in different mediums? (Graphs, picture, tables, words, etc.)

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Interpreting Data: To what extent can students interpret their findings in a thoughtful way, demonstrate that their study has deepened their understanding of the scientific concept and raise questions for future study that are both interesting and investigable?

Reflection: To what extent are students able to reflect about decisions that they have made that either worked or did not work, and reflect on how they might conduct this investigation differently in the future?

Communication: To what extent can students communicate the process, data and findings in a written and oral fashion?

Two strategies for assessing project-based science activities are provided here as examples.

Performance Assessment

Project-based instruction lends itself particularly well to performance assessment, that is, assessing students' actions during a task. This form of assessment is built around a performance task that allows for a certain kind of scrutiny. Performance assessment tasks should be grounded in real-world contexts, involve sustained work, blend content and process, present nonroutine open-ended problems, and require students to further define the problem as well as construct a strategy for solving it. Such tasks often blend individual student work in the beginning and in the end with a significant time of group work in the middle. Hence, teachers have an opportunity to assess individual as well as group work (Baron, 1991). Students are questioned before beginning such a task for their preconceived notions and conceptual understanding. During the sustained group work teachers observe students with specific criteria (that they have developed) that relate to conceptual understanding, scientific process skills, group and collaborative skills and communication skills. Greater insight into students' understanding is acquired through reviewing drawings, artifacts, written and oral presentations.

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Portfolio Assessment

Another form of assessment that is worth discussing for its potential to be integrated with project work is portfolio assessment.

Portfolio is a purposeful collection of student work that exhibits the student's effort, progress and achievements in one or more areas. The collection must include student participation in selecting contents, the criteria for selection, the criteria for judging merit and evidence of student self reflection.

— Paulson, Paulson, Meyer, 1991

Portfolios provide both teacher and student with a way to reflect not only on an end product but on continual evolving growth. For example, students may be able to note how they became more adept at designing experiments through the year or how they improved in their ability to present a logical argument to support or refute their hypothesis. They may note how their ideas about heating and cooling have changed after they have engaged in several investigations.

Unlike tests that enable teachers to compare and grade one student versus another student, portfolios encourage teachers and students to examine growth that has taken place for a particular student over a period of time. "The portfolio is something that is done by the student, not *to* the student." (Paulson, Paulson, Meyer, 1991) It encourages students to take responsibility and pride in their learning. Through this reflective process students learn to value their work and thereby learn to value themselves as learners. This self-assessment can form a crucial role in the development of students' understandings of their own learning.

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Overview

Professional Discussion Online

Purpose and Rationale

This activity is designed to provide a supportive structure which fosters substantive online discussion about teaching issues.

In addition to student research and project work, telecommunications can be used to support teachers' professional development and to build a teaching community of practice online. One way to begin to do this is through a structured discussion online about a compelling teaching issue. Ideally this is part of a larger, ongoing support plan to help teachers a they begin to make changes in their classroom practice.

Synopsis

The discussion moderator invites teachers to participate with a recruitment letter which specifies the parameters of the discussion. Participants sign up for the discussion, and it begins. The discussion can be expected to have three phases: An invitation or opening, the discussion itself followed by a summary of contributions, and then reflection on the process. Time to introduce in a workshop: 1 hour. Time for discussion: 1–2 hours a week over 4 to 6 weeks.

Preparation

Limit group size to 12-15 participants. It may be difficult for participants to track contributions in a larger group. We assume here that all participants have met one another face-to-face in the context of a professional development workshop prior to participating in this discussion. Participants may otherwise be reluctant to share their ideas around sensitive issues, unless it is structured as part of required course work.

Select an article on a topic of interest to your participant audience. Look for articles which thoughtfully treat a set of complex issues that teachers grapple with in their day-to-day practice (for instance, assessment), or which treat teachers' day-to-day practice itself (for example, constructivism).

Develop a single, driving question to instigate discussion around the article. (Include related sub-questions if necessary.) The question should be open, encouraging thoughtful replies.

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Professional Discussion Online

Exploration

Be clear about the commitment involved in participation so that teachers know what to expect and can decline, if necessary.

- *Establish a timeline and structure for the discussion. Putting a begin and end date on the discussion will make it feel more manageable to participants.*
- *Let teachers know how often they should expect to check the network, and the extent to which they are responsible for contributing.*

For example, a 4-week discussion about an article might be divided into 2 weeks of discussion about the initial driving question; a week of feedback on the summary of the discussion; and a week of discussion about the process. In this structure, participants could be expected to check the network 2–3 times a week, and to respond at least once, as appropriate, during each phase. Invite participants to suggest modifications to the proposed structure. This helps to establish a collaborative tone for the discussion to follow. Provide each participant with a copy of the article being discussed as needed.

Open the network dialogue with:

- *A re-statement of the structure, timeline, and expectations of participants; and*
- *An introduction to the driving question.*

Moderating the Discussion: Intervene as little as possible. Expect participants' first messages to be "informative" in nature—that is, responding directly to you and/or your driving question. Be patient. If you intervene, you are likely (a) to dominate the discussion; and/or (b) to entrench the dynamic in which participants respond directly to you, rather than beginning a dialogue among themselves.

If it appears to be appropriate or necessary to acknowledge individuals' contributions to the discussion—and it may well not be—consider doing this privately, e.g., by private e-mail, and not on the forum or to the entire distribution list for the discussion. If you use private mail, try not to address the content of the teacher's message. (See Sample Message A.) You do not want to set up a private conversation which parallels the larger public dialogue. If you acknowledge publicly, don't address the content of the teacher's message yourself; you will potentially set up a responsive participant-to-moderator dynamic or pattern which never develops into a group conversation. Instead, invite other participants to respond to the message.

If the group has difficulty launching a discussion among members, BE PATIENT. Recognize that it is generally more difficult to foster a

Sample story

Participants read Wynne Harlen's essay, "Discover, enquiry, interactive, constructive learning—what's the difference?" (*The Teaching of Science*, Harlen, 1992, chapter 6.) The questions, "What would different kinds of learning look like in the classroom? How would the learning process in each be the same? How would it be different?" were used to generate a discussion about shifts in approaches to science teaching.

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substantive discussion about professional issues online than face-to-face. If it is clear that the discussion is getting nowhere after at least half of the discussion phase has passed, you might try some techniques which work in group discussions offline, such as:

- *repeat the driving question, or*
- *invite participants to respond to one member's contribution.*
- *Another option is to continue without intervening and to bring up the online "silence" or dearth of discussion during the last phase of reflecting on the process.*

The Summary: It is important that the moderator's summary constructively reflects all participants' experiences of both the content and the process of the conversation. If the discussion has been too complex to develop a constructive analysis in the time period scheduled, simply summarize, but do not evaluate, each participant's contribution. Invite participants to comment on and add to the summary so that they feel that it accurately reflects their views and experiences.

Reflection

Stimulate reflection with one or two questions, such as

- What helped/hindered your reflection on the article?
- What helped/hindered you in considering the discussion in relation to your own practice?

This is also an opportunity for participants and the discussion moderator to reflect upon the role of the moderator in facilitating the discussion. You might ask,

- Which of the moderator's interventions or strategies fostered the discussion? Which interfered?

Sample A: Private Response

Chris,

Just read your message on the forum—glad to see you on board. Am looking forward to seeing other folks' responses.

Meghan

Sample B: Public Response

Chris,

Looks like you successfully posted your first message on the forum—well done.

How about others? Have you had an experience like Chris's?

Meghan

General Conditions for Supporting a Reflective Discussion Online:

- Provide a protected workspace for reflection—e.g., a closed bulletin board, or work on private e-mail, so that non-participants may not "wander in" to the discussion and disrupt it.
- Provide access and response to all messages which are part of the discussion.
- Communication must be asynchronous, to provide participants with time to reflect on the issues and on one another's responses.
- There should be a chronological record of the dialogue available. If you're working with e-mail distribution lists, you may need to keep a chronologically organized archive of the discussion offline, to be made available to participants upon request. A private bulletin board which automatically establishes a chronological record that all participants have access to at any time is ideal.

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Resource Material

Watching the Drops

The Science of the *Watching The Drops* Activity

Although the object of this activity is generating questions, there is something to be said for providing some of the answers. The following is a general discussion of what happens and why (and why not).

When the cylinder is first turned over, air bubbles stream up from the bottom and liquid starts coming out of the top, often in a stream initially and then fairly soon as individual drops. Once it settles down to drops, they come out of the nozzle evenly spaced, land on the spiral ramp and move down as a train of evenly spaced drops. These gather in the bottom, form a puddle and then gradually disappear into the bottom reservoir. After a time the emerging drops get smaller and the rate of dropping slows down.

Why do the drops maintain their mrop identity?

The colored drops and the clear liquid in the timer do not mix. Our common experience of fluids that do not mix is oil and water, and often people initially suggest the drops are colored oil and the clear liquid is water.

Why do the drops fall through the liquid?

This is a question about floating and sinking. In order for the drops to sink, they must be heavier than the same volume of the clear liquid. Thinking about this quality of floating and sinking, those same people who have suggested that the drops are oil realize that oil floats on water so they cannot be oil drops falling through water.

Why does the drop size and drop rate decrease with time?

This is related to the role of the air bubbles. Often people do not initially notice the air bubbles. That should suggest a question: When drops fall out the spout, why doesn't this create a vacuum in the top reservoir that quickly slows down and then stops the flow? The answer to that question is the air bubbles, and the answer to the question of slowing down is the lack of further air bubbles. Because air bubbles do not continue to go up as the drops fall out, a partial vacuum builds up in the reservoir that gradually slows down the drop flow.

Why doesn't fluid come back out the drain hole when the cylinder is turned over?

There are numerous designs that could explain this, such as a valve with a one-way flap. The design actually used involves a split level so that the entrance to the spigot is lower than the drain. This means the liquid pressure at the spigot is greater than the pressure at the drain, causing the drops to emerge there. Liquid pressure at any submerged point is dependent upon depth, upon the weight of liquid above. An example is in scuba diving, where the pressure gets greater the deeper you dive.

Why do the drops resist becoming puddles?

Each drop establishes a surface tension around itself, the result of the mutual pull of molecules (cohesion) toward the center of the drop. Although water mixes with itself easily, the drops do need to break this surface tension in order to do so. Sometimes that happens on a ramp as a result of bumping, sometimes at the bottom it seems to be a matter of time until the attractive forces win out. Another phenomenon involving a surface tension layer is water bugs walking on water in streams and ponds. There you can see the foot prints where the surface layer is slightly depressed under each of the bug's feet due to the weight of the bug.

Where to Buy the Drops Cylinder

The drops cylinder (sometimes called a "drops timer") is a popular toy that can be bought from The Forte Company, Cambell, CA 95008 408–559–3180.

Resource Material

Drops on a Penny

An Analysis of the Physics of Drops Piled Up on a Penny

Three forces are acting on a pile of water upon a coin: gravity, cohesion and adhesion. When the pile of water stays in place, the force of gravity (the weight of the water), which is trying to spread the water into a uniform layer, is not sufficient to overcome the forces holding the drops together. Cohesion is one of those forces. It refers to the attraction of like things, in this case, the attraction of water molecules to other water molecules. The teardrop shape of drops at the end of the dropper and the rounded shape of the pile of drops on the coin are essentially due to this. The result of this cohesion is surface tension. Water molecules are more closely packed at the surface since they are only pulled from below, as compared to water molecules in the middle of the pile of drops, which are pulled from all directions.

Adhesion, the third of the forces mentioned, refers to the attraction between unlike things, in this case, between the water and the coin. The force of adhesion tends to spread the water out uniformly over the surface of the coin and then down the sides. Therefore, adhesion in this case works against piling drops up on the coin.

Some of our initial data indicated that the number of drops possible on quarters did not differ very much from pennies but that there was a bigger contrast for quarters compared with dimes. This raised the question of whether the metal the coin is made of was a relevant variable.

Process Variables

Forces, however, are not the only variables affecting the results of this activity. The scattered data, and even opposite findings from different groups in the case of drops on the heads side versus the tails side of the coin, suggest that some other factors are varying. Questions of uniformity of drop size and procedure for using the dropper need to be checked. It is also possible that the balance of forces becomes very delicate as the maximum number of drops is approached, making it increasingly tricky, but not impossible, to add more drops.

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Resource Material

Heat, Temperature and Energy

Several themes apply to activities throughout this manual. Heat, temperature and energy is one such theme. Activities that involve heat, temperature, and energy include

Cold Hands/Warm Heart,

A Melting Popsicle,

Hot Cars and

Cooling Works.

We have provided Resource Material for each activity to address aspects of this theme that are unique to each activity. Presented here is a more general discussion.

Concepts and Context

Heat and light are probably the two forms of energy we are most aware of and have the most experience with. For instance, we are inclined to

- wear sweaters and coats and bundle up in winter;
- wear light, loose clothing in summer;
- sweat, pant and take a dip or shower when overheated;
- take our temperature when we are feverish;
- cook and serve hot food along with cold drinks;
- light up the darkness, shade out bright glare; and
- use furnaces, air conditioners, fireplaces and fans.

Concepts that underlie each of these phenomena involving heat, temperature and energy include

- transfer of energy from place to place,
- transformation of energy from one form to another,
- rate of change and
- intensity as a measure of amount per unit.

In addition, studying heat, temperature and energy involves processes that apply more broadly to other phenomenon as well. These processes include

- measurement,
- recording,
- data representation and
- data interpretation.

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Resource Material

Heat, Temperature and Energy (continued)

Heat Versus Temperature

There is a basic confusion common for students of all ages: the distinction between heat and temperature. People tend, incorrectly, to use these two words interchangeably. Heat refers to the total amount of heat energy contained in an object; temperature measures the intensity level of that heat energy; i.e., energy per unit of mass or volume. Think of a thimble and a bath tub, both full of hot water at the same temperature. The total amount of heat in the thimble of hot water is much less than the amount of heat in the bathtub, even when their temperatures are equal. This explains why the thimble of water will cool to room temperature so much faster.

Here are other examples of this distinction between total amount and intensity, some of which are not confusing at all:

- weight versus density, where density is weight per unit of volume;
- total cost versus price per unit, from buying vegetables to filling your car with gas; and
- tax versus tax rate.

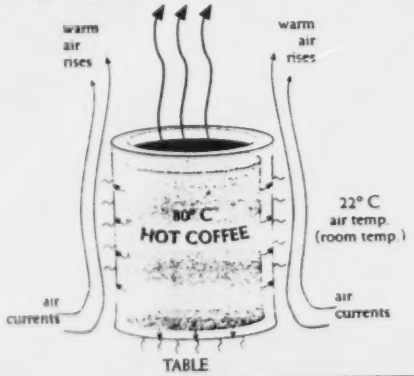
Heat Transfer

How is heat energy lost? There are a number of underlying principles; these three are foremost:

- Heat energy always flows "downhill"; i.e., heat flows from a higher temperature place to a lower temperature place.
- The rate of heat flow depends in part upon the difference between the two temperatures; e.g., the difference between the temperature of a cup of coffee and room temperature.
- Hot things cool faster than warm things, where "faster" refers to the time it takes to cool a given number of degrees. A cooling curve graph illustrates this changing rate of cooling. The shape of the cooling curve shows that as the container approaches room temperature it loses heat more slowly.

Using the example of a cup of hot coffee, the heat flow occurs in a number of ways. For one thing, the hot coffee heats up the cup. Then the hot sides of the cup heat up the nearby air, the bottom of the cup heats up the table top. The air in contact with the surface of the coffee is also heated.

If this were the whole story, the heat flow might quickly stop since the cup and the air around it are heated to the same temperature as the hot coffee. With the temperatures the same, there would be no heat exchange and the system would be at equilibrium. In fact this does not happen because air currents are set up; the hot air is displaced by denser, cool air and rises. This new cooler air is heated, taking more heat away and the process continues until the new air is no longer cooler, i.e., the hot coffee has cooled to room temperature.



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Resource Material

Heat Transfer (continued)

When you go to a place like Dunkin' Donuts to get a takeout cup of coffee, how do you keep it hot as long as possible, or in other words, how do you control the rate of cooling? This is where factors such as the material the cup is made of become important. Some materials conduct heat better than others, e.g., tin cups versus styrofoam cups. The terms heat conductors and heat insulators refer to this property.

Some people use a special plastic car cup with a top and double walls with air in between. How does the Dunkin' Donuts cup compare with this car cup? They both cut down on the heat loss at the surface by including a top. The Dunkin' Donuts cups are made of a paper product, however, and if you hold both cups, you can evaluate their relative effectiveness as Heatkeepers by feeling which cup is hotter on the outside.

Sometimes instead of takeout you are faced with rush-out, but your coffee is too hot to drink. One solution, frowned upon by polite society, is to pour coffee into the saucer. This provides a greater surface area in contact with the room air and allows for quicker cooling.

Another way heat is lost by a hot body is by radiating heat energy in the form of infrared radiation. Since infrared radiation is not visible to the naked eye, it is hard for us to appreciate this factor. One way to explore it would be to use aluminum foil as a cover. Since the silver foil reflects infrared, comparing this with an identical cup using a paper or plastic cover would reveal the relative importance of this form of heat transfer. Inside a thermos bottle, the silver coating you see on the outside of the glass wall insulates against this heat loss. In a double-walled vacuum thermos, the air between the two walls is pumped out, since a partial vacuum insulates even better than a dead air space.

Cooling Works is all about heat transfer, and this concept is an important part of *Hot Cars* and an aspect of *Investigating Hand Temperature* and *A Melting Popsicle*.

The words used to discuss heat transfer are typically the main point in science textbooks: conduction, convection and radiation. In the whole description above, there has been an attempt to only use those labels in context where they help when trying to explain the processes of cooling.

Energy Transformation

A common process in several of the units involving heat and temperature is the conversion of energy from one form to another. A prime example is the heating of the earth by the sun, not by heat from the sun but by light that is converted to heat energy after it arrives at the earth.

How does that happen? Keeping in mind the Conservation of Energy Principle, if the sun heats the earth then the transfer must "use up" some of the light energy. One way to detect differences in the energy transformation of sunlight to heat is to touch different colored objects that are all sitting in direct sunlight. Darker objects tend to absorb more light; lighter objects reflect more light, thus absorbing less. Mirrors reflect almost all the light. It is the absorbed light that is transformed to heat. If you were to line up a series of objects on a hot sunny day and come back an hour later, black things might be too hot to touch, yellow and white things might be warm but not so hot, and the mirror would be coolest. A set of croquet balls is good for testing this since they reduce the number of variables, given that the size and material are the same and the only difference is the colors.

Hot Cars is principally an investigation about how different materials affect the transformation of sunlight to heat. That is also a factor in *A Melting Popsicle* when holding the Popsicle in the shade versus the sunlight suggests that a lemon Popsicle should last longer than a black raspberry one. *Cold Hands/Warm Heart* explores a more subtle case of both these concepts of transfer and transformation.

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Resource Material

Cold Hands/Warm Heart

Body Heat and Temperature

Heat is produced in the body during all bodily processes, i.e., during all metabolic activity. When activity increases, as for example during exercise, more heat is produced and body temperature tends to rise, but the body has mechanisms for counteracting the rise.

The tissues and organs of the human body function best when they are maintained at a relatively constant temperature near 37° C. The temperatures of the peripheral tissues (e.g., skin, muscles, and subcutaneous tissues) are generally cooler than the central organs, and they usually fluctuate over a range between 20° and 40° C, depending on conditions in the surrounding environment.*

Since the resting temperature varies from individual to individual, there is a range of temperatures that are considered normal. Furthermore, for any one individual, temperature varies during the course of the day, being lower in the early morning and higher later in the day.

Regulation of Body Temperature

To maintain a constant temperature, the body uses two systems:

- voluntary behavior, such as wearing protective clothing, using air conditioning and the like; and
- physiological regulation, automatically carried out by the nervous system.

The way the automatic process works is through temperature receptors in the skin and body core, which can detect the temperature level and the rate of temperature change. When a change is sensed by these receptors, they transmit the information through nerves to the hypothalamus at the base of the brain. The hypothalamus then generates the appropriate signals to the circulatory system to change the distribution of the circulating blood.

For example, when the body temperature rises, the instruction goes out for the skin blood vessels to dilate, thus enabling them to bring more blood to the skin surface — you will be flushed — so that more heat can be lost through convection and radiation. In addition, instructions go out to the sweat glands to increase the rate of sweating and thus of heat loss through evaporation. When the body cools down too much, increased heat production is brought about by causing the muscles to shiver and constricting the skin blood vessels to curtail heat loss.

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Resource Material

A Melting Popsicle

Why does the Popsicle melt?

All solids have a melting temperature, the temperature at which they change from a solid state to a liquid state. For the things in our experience that are solids, the melting temperature is typically higher than normal outdoor temperatures: rocks, for instance, and the metal and plastic and rubber that makes up a car. The most familiar exceptions are snow and ice. We all know that these melt when it gets too warm—higher than 32° F, or 0° C. A Popsicle is just a colored and sweetened version of ice, so we would expect that it too would melt when its temperature gets above 0° C.

What determines how fast the Popsicle melts?

The two main factors are the difference in temperature between the Popsicle and the air around it, and the surface area of the Popsicle in contact with the air. A third factor, commonly experienced outdoors, is whether or not the Popsicle is in direct sunlight.

Why does the rate of melting change, initially getting faster?

When you first take a Popsicle out of the freezer, its temperature is certainly less that 0° C. What is more, that is its temperature throughout, from the surface to the middle. This means the initial heating at the surface is counteracted by a continuing cooling from inside the popsicle. Over time, however, the core also gets warmer and this effect diminishes causing the rate of melting to speed up. Back on the street corner, this is why we tend to say, "Hurry up and finish your Popsicle before it starts to melt."

Why does the rate of melting slow down at the end?

The speeding up of melting in the beginning is related to temperature differences. The final slowing down is due to surface area changes. As the size of the Popsicle gets smaller, there is less surface area in contact with the air, and the rate of melting slows down as a result. You may not notice this if the Popsicle falls off the stick.

How can we measure the rate of melting?

The workshop example of collecting the drips is one way. Another way would be to suspend the Popsicle from a balance arm in such a way that the drips fall free. This would then allow measurements of the change of weight as the Popsicle melts. There is an important conceptual distinction using weight compared to collecting drips. The volume of drips each minute is a direct measurement of the rate of melting. The weight each minute, however, is not. The rate of melting is the difference in the weights from one minute to the next. Comparing the two methods could be a valuable learning experience.

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Resource Material

Cooling Works

General Information

How is heat energy lost? There are a number of underlying principles.

- For one thing, heat energy always flows "downhill," i.e., heat flows from a higher temperature place to a lower temperature place.
- The rate of heat flow depends in part upon the difference between the two temperatures, e.g., the temperature of the water and room temperature. Hot things cool faster than warm things, where faster refers to the time it takes to cool a given number of degrees. The cooling curve graph illustrates this changing rate of cooling. (See graph with Challenge Teacher Notes). If the rate of cooling were the same all the way down to room temperature, the graph would be a straight line instead of curved . The shape of the cooling curve shows that as the container approaches room temperature it loses heat more slowly.

The heat flow occurs in a number of ways: The hot water heats up the container. The hot sides of the container heat up the nearby air, and the bottom of the container heats up the table top. At the surface of the water, the air above is also heated.

If this were the whole story, the heat flow might quickly stop when the container and the air around it are the same temperature as the hot water. With the temperatures the same, there would be no downhill and the system would be at equilibrium. In fact this does not happen because air convection currents are set up; the hot air rises and cooler air, cooler than the container and water surface, replaces it. This new, cooler air becomes heated, taking more heat away, and the process continues until the new air is no longer cooler, i.e., the hot water has cooled to room temperature.

Controlling the rate of cooling, therefore, involves controlling the transmission of heat away from the surfaces of the container and the water. This is where factors such as the material the container is made of and the size of the container become important. Some materials conduct heat better than others, e.g., tin can versus plastic cups. The terms heat conductors and heat insulators refer to this property. Larger containers have more surface area in contact with the surrounding air so the transmission of heat from the container to the air can happen at more places at the same time. An extreme example makes this clear: think of cooling a cup full of hot water versus pouring the hot water out on a large cookie sheet. And finally, covered containers reduce heat loss from the surface of the hot water since the enclosed air quickly becomes the same temperature as the water, or almost. The enclosed hot air does heat the cover which in turn heats the air outside the cover, but the process is much slower because trapped air is a fairly good insulator. In house insulation, a dead air space is included for the same reason.

Another way heat is lost by a hot body is by radiating heat energy in the form of infrared radiation. Since infrared is not visible to the naked eye, it is hard for us to appreciate this factor. One way to explore it would be to use an aluminum foil cover on a container with a large water surface. Since the silver foil reflects infrared, comparing this with an identical container using a thin paper or plastic wrap cover would reveal the relative importance of this form of heat transfer.

The words for all this heat transfer are typically the main point in science text books: conduction, convection and radiation. In the whole description above, there has been an attempt to only use those labels in context where they help when trying to explain the processes of cooling.

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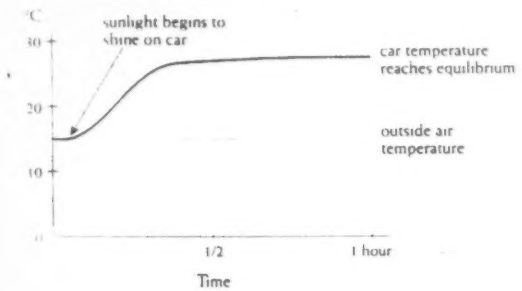
Resource Material

Hot Cars

In the following notes, the emphasis is upon three aspects of the science underlying this phenomenon, aspects which are also typically not well understood. These are 1) the difference between heat and temperature, 2) the concept of rate of change and 3) the concept of equilibrium. This activity in many ways is similar to the *Cooling Works* activity.

If one were to place a temperature probe and computer in one's car before parking it in the open sunshine, what would the temperature graph look like?

Initially the graph will rise sharply as the car heats up, but as the car gets hotter the graph will become less steep and finally flatten out as the temperature reaches a limit.



Why does the graph flatten out?

There are two opposing processes going on here. On the one hand, the sun is heating the car up, so heat energy is being added to the car. This results in an increase in the interior temperature, and as a result, the graph will show a rising temperature. As the car gets hot, however, the counter effect of losing heat to the surrounding environment begins. This will occur as soon as the car is hotter than its surroundings, and the rate of heat loss depends upon the temperature difference. The greater the difference in temperatures, the greater the rate of heat transfer from the hotter car to the colder air outside. Eventually these two rates of heat transfer become equal, one tending to heat the car up and the other tending to cool it off. When this happens the temperature stays constant, and the system is said to be in equilibrium. Note that the heating and cooling are still occurring but at equal and opposite rates. An analogy is a sink, with water from the faucet filling the sink while an open drain empties it. If the two rates are equal, then the level of water will stay the same; this system is also in dynamic equilibrium. In this sink example the faucet is analogous to heating up, the drain is analogous to cooling, and the water level is analogous to the temperature.

You may want to build a model of this, using a coffee can for the sink, making a fairly small hole in the side of the can near the bottom and rigging a water source above the can with a tube and a clamp that allows you to regulate the rate of water flow into the can. For different rates of flow into the can, there will be different equilibrium water levels.

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Hot Cars (continued)

What would affect the equilibrium temperature in our hot car example?

Since there are two rates involved, changing either one will change the equilibrium temperature. For the rate of heat gain, assuming the source of heat energy does not change (the sunlight reaching the car), then the issue to focus on is the conversion of sunlight to heat energy. This conversion happens at both the exterior and the interior of the car.

At the exterior, sunlight striking the car body gets absorbed as well as reflected. The absorbed light is converted to heat energy which heats up the car body. The car body material, generally metal, transmits that heat from the outside surface to the inside surface, where it heats up the air inside the car. The balance between reflected and absorbed light depends upon the color of the car; dark colors absorb more, light colors reflect more. The choice of colors for home roofing is often based on this concept. In the north, people tend to use dark tiles to add heat from the sun; in hotter climes, people tend to use light color tiles to reflect the sunlight and avoid extra heating.

In the interior of the car, sunlight coming through the windows strikes the seats and dashboard and inside paneling of the car. There are two ways to affect this: change the windows and change the colors in the interior. The use of the sunshield across the windshield of a parked car or changing the color of the seat covers are examples.

Controlling the other process, the rate of heat loss is primarily a matter of making a tight ship. As we know, opening the windows is a way to cool the car down enough so you can bear to get in. Air currents to the outside are one way in which the heat is lost. Transmission of heat through the car body, from the inside to the outside, is a second way. This is analogous to the heat transfer coming into the car, with an added variable, namely the possibility of insulation. Lining the inside of the car helps to keep the heat in, as well as improve the appearance. If insulation slows down the heat loss more than it affects the rate of heat gain, then the equilibrium temperature will be higher than for an uninsulated interior.

Why don't cars heat up in the winter?

They do; they just don't get too hot to sit in. It remains an unanswered question, however, how the increases in temperature compare between summer and winter. Although the car may not have changed, there is a difference in both the outside air temperature and the angle of the sun. In the winter, in the United States, the sun is lower in the sky than in the summer. The result of this lower angle is that the sun's rays pass through more of the earth's atmosphere before they reach the earth. This means more of the light gets absorbed by the atmosphere. The lower angle also means that the sunlight is spread out on a horizontal surface, such as the car top, compared to a light beam coming down at right angles. Spreading the beam out means less energy per unit of area. So the factors that affect the rate of heat loss may not have changed, but the rate of heat gain should be lower. This predicts that the overall change in temperature in winter is less, but it not zero.

How is designing the best Heatkeeper different than analyzing the hot cars?

In the *Cooling Works* unit, the challenge is to design one container that will keep in the heat and cool very slowly compared to another that cools rapidly. For both containers, there is no continuing source of heat such as the sun provides in the *Hot Cars* unit. Therefore, there is no equilibrium temperature as there is in *Hot Cars*, at least not until the containers cool to room temperature.

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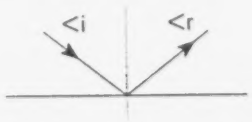
How Does Light Behave?

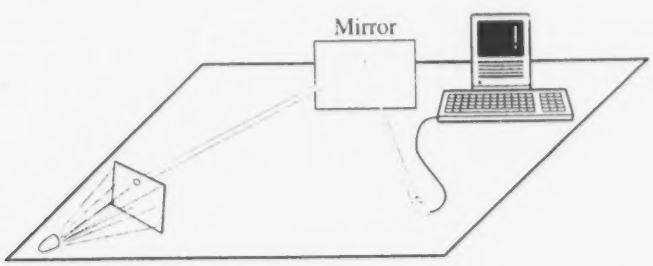
Reflection of Light

A light ray reflected by a mirror or other surface bounces away at the same angle as its angle on the way to the mirror.



Angle of Incidence Equals Angle of Reflection

This can be discovered using a light probe, a mirror and a light beam, such as light from a flashlight coming through a small hole in an index card. For any position of the mirror, where does the probe "see" the reflected light? This can start in two dimensions, with everything on a table top, and then go to three dimensions where the mirror is held vertically above the table top, perhaps against an adjacent wall.



Angle of incidence equals angle of reflection also applies to whether or not an object can be seen in a mirror. In this case the person is the light receiver. Often people don't think of it this way, however. The following activity can be a way to stimulate discussion and reflection about this:

> With people sitting around the room, place a covered mirror at eye level on the wall, or indicate where a mirror will be placed. Ask who will be able to see a given object in the mirror, perhaps one of the people in the room. Ask who will be able to see themselves. Repeat the same questions, but this time with the mirror high on the wall, above peoples' eye level.

In every case, in order to see the object in the mirror, the light path from the object to the mirror and then to your eye has to be such that the angle of incidence equals the angle of reflection. For the mirror high on the wall, this means both the horizontal and the vertical components of the angle.

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How Does Light Behave? (continued)

Color

The color of something depends upon the light that reaches our eye. We tend to think of color as an inherent property of the object. The underlying assumptions, however, are that it is being viewed in white light and without wearing rose-colored eye glasses.

When white light shines upon a colored opaque object, such as a blue notebook, the notebook reflects mostly the blue part of the white light and absorbs the green, yellow and red parts. We see it as blue because it is the blue light that reaches our eye. The idea that the blue is part of the original white light and not just a change in the original light can be seen using the light probe to compare the brightness of the light before and after reflection. The change in brightness can mostly be attributed to the parts of the original white light that have been absorbed by the object. Since the color of most everyday objects is not a pure color but depends upon the dominant color reflected, it can be interesting to compare various objects.

If we look at that blue notebook through rose-colored glasses, however, the glasses transmit the red and absorb the blue, green and yellow. So the blue notebook absorbs the red, and now the red filter absorbs the blue; the result is that we see a black notebook. We would get the same perception by shining red light on the notebook. In both cases, there is nothing left to reach our eye, and black is the color of no light. Using a probe you can check how black it is by noting the level of remaining brightness. Lacking pure dye colors for the notebook and pure filter colors, some light will typically survive this double absorption by colored notebook and colored filter.

Personal Science Laboratory (PSL) Light Probes

There are two different light probes included with the PSL kit, a photometric light probe and a radiometric light probe. For this activity it is preferable that everyone use the same type probe so that data can be shared between groups. For experiments by a single group, however, either probe is fine.

The difference between the two probes is associated with the difference between perception and reality. In this case, perception refers to light as we see it. Between the arrival of light at our eyes and our interpretation of its brightness, our physiology intervenes. The photometric light probe "sees" light the same way our eyes see light. Since our eyes are not equally sensitive to all the colors of visible light, e.g., yellow more than red or blue, the probe includes a color filter to adjust its sensitivity in the same way. The radiometric light probe, on the other hand, sees it as it is. This means that two light sources of equal intensity, one yellow and the other blue, will be seen as equal by the radiometric probe but unequal by the photometric probe.

Probe calibration. Every probe includes a tag that gives the calibration number for that probe. Use the calibrate menu option to enter that number before using the probe for any experiments.

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Resource Material

Motion

Representing Motion

Students often focus on the specific without noting the whole, i.e., on the coordinate values for specific points but not the overall shape of the graph. The opening "match the graph" activity, in which the axes are shown without any scales of values, makes overall shape the main clue to use. Asking students first to put in words a general description of the motion shown on the graph can help clarify for them what is going on.

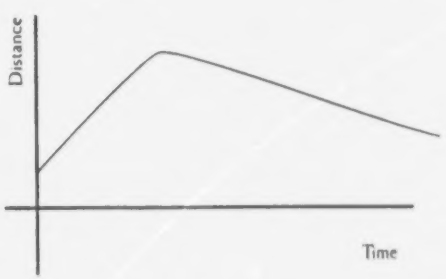
The value of describing the motion in words is particularly true when thinking about speed. When looking at a distance graph, speed, as the rate of change of distance, is shown by the slope of the graph, not by any one point on the graph. When looking at a speed graph, on the other hand, speed is the value at any given point. A common confusion, however, is to interpret a flat horizontal portion of a graph to mean the object has stopped when, in fact, it is travelling at a steady speed.

Speed versus Velocity

The MBL motion software can produce both distance over time graphs and velocity over time graphs. For the velocity graph, the velocity axis includes both positive and negative values. In the previous section on graphs, speed is the word we have used to describe the change of distance over time. This is appropriate for upper elementary science students. Velocity is like speed but includes the concept of direction: positive velocity is speed going away, thus increasing distance away, and negative velocity is speed coming towards, thus decreasing distance.

Rate of Change

Rate of change is an important property in many given situations, but "current level" is the property that is more often focused upon and confused with rate of change. As an example of confusing "level" and "rate," consider a distance graph of someone moving rapidly away from the probe and then returning very slowly.



Students, when asked where the person was moving fastest, often pick the highest point on the graph. This point coincides with the furthest distance away, not the fastest speed; in fact, the speed is zero as the person turns around.

Rate of change is an important concept in this and other activities such as *Cooling Works* and *Hot Cars*, and the connection is worth pointing out. Here are further connections with the world outside:

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Resource Material

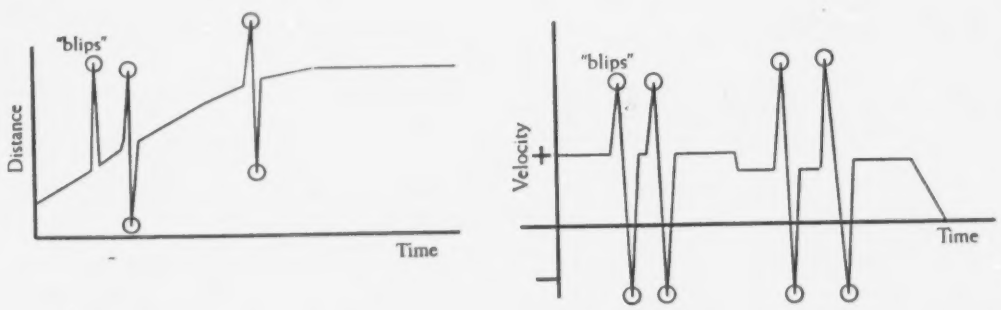
Motion (continued)

- *Sustainable global forest.* The tropical rain forest is immense in scope, yet the rate at which it is being cut down could mean there will be very little left in the foreseeable future. A sustainable global forest means the rate of cutting is equal to the rate at which new trees grow to harvestable size.
- *Global warming.* This is linked to the build-up of carbon dioxide in the atmosphere. To date the rate of change of carbon dioxide has been increasing from year to year. Failure to control this accelerating increase will result in a quadrupling of the carbon dioxide level before the end of the next century.
- *Inflation.* The percent refers to rate of change. This is in contrast to another economic indicator, percent unemployment, that refers to the number (total amount) of people out of work.

Probes

The distance probe employs the same mechanism used by a bat to sense insects: it sends out an ultra-sonic sound pulse and listens for the return echo. Distance to the object is computed based on the time elapsed between sending the original signal and detecting the return echo. Speed (velocity) is determined by finding the change in distance during several pulses and computing the change in distance per unit of time (seconds).

In using the probe, there are several aspects the user needs to understand. For one thing, the probe cannot detect objects closer than about 50 centimeters. This is because the probe cannot simultaneously send pulses and detect echoes. For objects too close, the echo from the front of the pulse gets back to the computer before the end of the pulse has been sent.



Graphs of motion often include noise in the form of blips. These occur when the probe does not detect an echo, typically because the sound reflection is deflected. For instance, when a person is moving, the echo may be deflected by loose clothing that reflects the sound to the side. The computer interprets this as meaning the object is suddenly too far away, thus the blip up to the top of the screen. Since the computer calculates speed on the basis of change of distance, distance blips will translate into speed blips.

A solution to this problem is to be sure there is a flat reflecting surface, such as holding a note pad if the object is a person, and to check that it is facing toward the probe.

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Resource Material

Telecommunications

Telecommunication technology is currently employed widely in business and research — from automated teller machines (ATMs) to massive data collection efforts — and its uses are expanding rapidly. With the advent of easy-to-use commercial services such as CompuServe, Prodigy and America Online, personal use of telecommunications is also on the rise and entrepreneurial teachers are beginning to bring it into their classrooms.

The principal power and potential of telecommunications is twofold: It supports long-distance research collaborations and provides access to a vast — sometimes overwhelming — wealth of resources and information.

For elementary students, telecommunications-mediated collaborations provide an opportunity to share research explorations and results with an audience of fellow students; students' writing improves when they are communicating with peers. Telecommunications can make available a variety of resources and information, such as news, weather data, ERIC (mediated by their teacher). It provides students with access to a geographically distributed data pool, either regional or national. And the built-in time lag between asynchronous communications provides an opportunity for students to conduct investigations offline and to reflect on their learning as they prepare to communicate their work.

For the elementary science teacher, telecommunications can provide access to a professional community of practice, breaking down the isolation of the individual in his or her classroom. It may offer access to developers, researchers and scientists who are interested in working with teachers to improve science education; and it can provide access to an array of information resources on both education and science, as well as the opportunity for both teachers and students to participate in network-mediated science projects.

While the number of educational networks for students and teachers is growing, there are essentially two types:

1. highly structured networks that support specific curriculum units for fixed, pre-established periods during the school year (e.g., NGS's Kids Network), and
2. more open, free-form networks in which teachers and students take greater responsibility for the content of network communications (e.g., K-12Net).

The Hands-On Elementary Science project focuses primarily on the educational uses of the second type of network, since commercial providers of the first type of network generally provide extensive written curricular materials. If you have the resources but are uncomfortable with telecommunications, you may find it useful to begin with a more structured network and materials, moving to a more flexible network once you have become comfortable with the technology.

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Telecommunicatons (continued)

What is Telecommunications, and What is a Network?

Telecommunication means literally "communicating across distances." Computer telecommunications technology allows people to send data from one computer to another, whether that computer is in the next room or across the world. The data can be text, graphics, computer code or even video and sound.

A telecommunications "network" is literally two or more computers connected by cables, phone lines and modems. "Network" can also refer to the group of people and services who are connected. People today talk about "networking" with their friends or peers to exchange information, carry on conversations or help each other find jobs or services. Or they join a commercial network service, such as America Online, that provides them with the ability to send and receive information such as electronic mail (e-mail), post messages on electronic bulletin boards, access databases or connect to a travel agency, their bank or the weather service.

Telecommunications technology for the computer requires both hardware and software.

Hardware. Data is telecommunicated from one computer to another either through a cable that connects two or more machines (local area network) or through data or voice lines used by the telephone (wide area network) that are connected to the computers by modems. A modem is the device that translates data from the computer to the telephone line and then back into data at the receiving computer. The speed that the modem or the cables can transmit data is called the *baud rate*. The higher the baud rate, the faster the transmission, which is important because you usually have to pay the telephone company and a commercial network service for the time you are "on line."

Software. There are myriads of software programs designed to run your modem and connect you to a network. To communicate on a network, both sender and receiver can have different computers and modems, but both need software that will let each read what the other has sent. Many commercial networks, such as Prodigy or America Online and educational curriculum publishers such as NGS Kids Network, give their users software when they join.

What Is A Local Area Network?

A local area network (LAN) is typically used to connect several computers in different classrooms to a shared printer. A LAN is usually confined to a single building, in part because of the physical limitations of the cable used to link the computers together. While a LAN may have a gateway to other, outside networks, the majority of its traffic tends to consist of communications among the computers that it physically links together.

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Telecommunications (continued)

What is a Long-Distance Network?

Long-distance networks, or Wide-Area Networks (WANs) are networks of computers located at different geographical sites that are linked through telephone lines and other data services. Usually via personal computers, users dial a local "host" computer, or file-server. Here they can access bulletin boards and mail-boxes to share messages or data, or access public information databases such as ERIC. The host computer (for example, a commercial service such as America Online) makes sure that mail and data are delivered to the correct "address," typically to the recipient's account or to a local Bulletin Board System (BBS). Some distance networks have "gateways," or direct connections, to several networks so that messages and files can be sent directly from one site to another. Typically these gateways are more sophisticated and expensive.

What You Will Need To Get Started With Telecommunications

Computer, including monitor (screen)

Memory (also known as random access memory or RAM)

At least 1 floppy disk drive

Modem (built in to the computer or as a separate box cabled to the computer)

Interface card for modem (as needed, depends on your computer)

Cables: In addition to the cords associated with the computer — power cords for computer and possibly also the monitor; keyboard-to-computer and mouse-to-computer cord if the modem is not built into the computer; and a PhoneNet cord from the telephone jack to the modem

Telecommunications software

Direct outside telephone or data line, installed, or any voice-grade telephone line that does not have to go through an operator for an outside connection

Membership in a telecommunications network (this will probably be an ongoing periodic charge — see below)

Hard disk drive, which is an easier facility for long-term storage than floppy diskettes

Costs

Possible ongoing charges include (these will vary widely, depending on your situation):

- technical support
- system repair and maintenance,
- software and hardware replacement and upgrades,
- monthly telephone line fee,
- other monthly line fees and
- telecommunication network charges (these may be variable or fixed depending on the service). Charges based on connect time can generally be controlled somewhat through efficient network use.

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Telecommunications (continued)

Troubleshooting Technical Challenges

Implementing telecommunication in the classroom (or even the school) is more likely to be difficult than not. Often the biggest obstacle is accessing to a direct outside telephone line. Some strategies for overcoming this are:

- Share an existing outside line. Often, telecommunications software can be programmed to happen outside school hours, so it won't interfere with workday calls.
- If there is an outside line available, but no phone jack in the classroom, it's possible to string a long cable from the line into the classroom.
- It may be more expedient to call the telephone line to be used for telecommunications a "data line." Although you are likely to want a voice-grade or voice-quality line, a telephone does not need to be attached to it in order to telecommunicate. This will also minimize the possibility that anyone will make unauthorized calls on the line.
- If at all possible, get help from your school or district technology coordinator, or similar contact person. He or she may be able to lend expertise and offer invaluable support to your efforts.

Troubleshooting Administrative Challenges

Consider the following arguments if your administration is dragging its heels about implementing telecommunications (Roberts, et al, p. 140 ff.):

- The school's official philosophy statement probably includes as a goal preparing children to become constructive members of society. You may argue that using telecommunications is on its way to becoming a basic skill.
- Telecommunications can support 3 established curricular goals: communication skills, collaborative skills and thinking skills.
- Demonstrate the technology to your administrators.
- Ask to serve as a pilot project or test site.
- Fundraise outside of the school.
- Get your administrator online.
- Provide administrators with information about how other schools are implementing telecommunications.

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Telecommunications Vendors

Local Area Networks

The project used Snap Mail on an AppleTalk network with Macintosh computers to simulate telecommunications for participants.

Snap Mail can be purchased directly from the publisher:

Casady & Greene, Inc.
22734 Portola Drive
Salinas, CA 93908-1119
408/484-9228 or 1-800/359-4920

As of this writing, Snap Mail's pricing schedule is as follows:

5 sites (users)	$125
10 sites	$200
50 sites	$900

Snap Mail is currently sold only in these increments. Thus, if you needed software for 12 sites, you would have to purchase one 10-pack and one 5-pack. Casady & Greene offers a 10 percent discount for educators who order directly from them.

Snap Mail can also be purchased from MacWarehouse (800/255-6227) or Mac Connection (800/622-5472). These distributors may not offer educator's discounts.

What You Need to Run Snap Mail

Snap Mail can be run on a Macintosh Plus or later model which has at least 1 MB of RAM and is connected to any type of AppleTalk network, including LocalTalk, PhoneNet, EtherTalk, TokenTalk and Apple Remote Access. Although Snap Mail can be run from a floppy, a hard disk is recommended. Snap Mail requires 425K of hard disk space.

Snap Mail will run under both System 6 (Version 6.02 or later, Finder or MultiFinder and System 7 (Version 7.01 with Tuner 1.1.1 or later).

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Telecommunications Vendors (continued)

About the AppleTalk Network

There is a limit to how long your AppleTalk network may be distancewise. The signals transmitted by devices (computers and printers) over the network degrade as they travel, limiting how long the LAN can be. The total length of your network is directly dependent on the gauge of the cable used. Different types of cable have different signal strengths. If 22 gauge cable is used, the total length of all of the wires in the network must be less than 4000 to 4500 feet. As the gauge of the wire rises, the maximum length of the network drops dramatically: 24 gauge wire can support only 3000 feet of network; 26 gauge only 1800 feet. (Wide Area Network cables use signal refreshers to clean up transmissions and send them on their way.)

Wide Area Networks

Internet — Getting Hooked Up

(Information is from NSTA *Reports!*, May/June 1993.) Probably the most common way for a school or class to connect to Internet is through a local college or university. Contact the "academic computer administrator" (or someone with a similar title) at a nearby institution and ask how you can set up an Internet "account." The word *account* is somewhat misleading because there is generally no cost to you; the only cost you will incur for any activity on Internet is for the initial phone call via modem to the institution where you have the account. All additional connections on the network are free.

Other ways to hook up to Internet are through commercial Internet providers such as CERFnet, Educom, and NEARnet, and through such commercially available online services as CompuServe, Prodigy and America Online. However, on these services, you will only be able to send and receive e-mail; you will not be able to tap into the vast information resources of the network.

Here are several introductory books that explain how to connect to Internet. All are available in local bookstores.

- *Internet Companion: A Beginner's Guide to Global Networking*, by Tracy LaQuey and Jeanne Ryer, 196 pages, $10.95. Published in 1993 by Addison-Wesley. (Parts of the book are available on Internet by file transfer from WORLD.STD.COM and in the directory /OBS/The.Internet.Companion/. Users needing help can send an e-mail message to OBS@WORLD.STD.COM).
- *Internet: Getting Started*, by April Marine and others, 360 pages, $28. Published in the SRI Internet Information Series by Prentice Hall in 1992.
- *The Whole Internet: User's Guide and Catalog*, by Ed Krol, 376 pages, $24.95. Published by O'Reilly and Associates in 1992.

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Resource Material

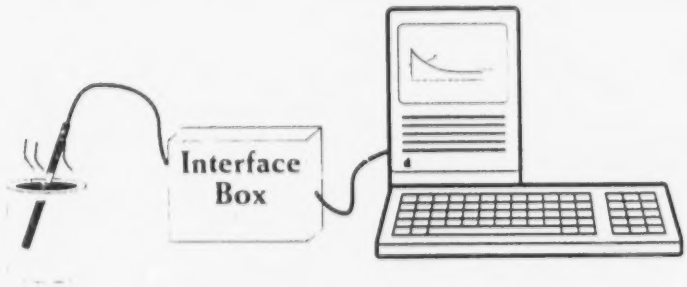
Microcomputer-Based Laboratories (MBL)

Imagine a tool that helps a learner to see, to hear, to gather data and then to organize and represent the data gathered. The MBL is such a tool. A key component of the MBL is a sensor, commonly called a probe. There are different sensors for different phenomena — temperature, light, motion, pH, sound — and others just as there are thermometers and light meters. On the MBL, however, these sensors are connected by an interface box to a computer. The MBL software in turn graphs the data on the computer screen as the experiment is in process. The software lets the user decide how often to sample the data and what kind of graph to display it on, and then analyze the data with various tools after it is collected.

How MBL Supports Learning

Many elementary teachers who have computers think of the word processor as a tool that facilitates the processes of writing and editing so that students may focus more on their thinking. In many ways, the MBL is analogous to the word processor in that it facilitates the *process* of gathering, representing and interpreting data. This provides more opportunity for learners to pay attention to the data—to interpret it, redisplay it and analyze it to inform their understanding of the phenomenon. Since the time span between changing a variable in their investigation and seeing the results is shortened, learners can ask more "what if" questions and are more likely to revise their test design and try it again.

For example, imagine placing a temperature probe in a cup of coffee. The computer is told to sample the data every 1/2 second. The user chooses to represent the data as a graph of temperature over time. As the coffee cools, the graph changes to reflect the new temperatures. After a couple of quick tests, the user begins to notice that each graph of the temperature change has a similar shape: a cooling curve. The curve represents the rate of cooling: the faster the cooling, the steeper the curve. Suddenly a scientific concept that was once very abstract is concrete and accessible for analysis. The user might then add a second temperature probe, add a second graph to the screen, and run a new test comparing coffee cooling in two cups: one paper and one styrofoam.



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Microcomputer-Based Laboratories (continued)

The MBL also introduces learners to some standard representations of science data, especially bar graphs for discrete data and line graphs for continuous data (data that changes over time). Learners learn the "language" of graphing in the process of using the MBL to further their own understandings. Learners also need experience creating their own representations of data, for there are many more ways to "see" patterns and express understandings than those used by the computer. Specifically, MBL allows learners to:

Measure events that happen very slowly. The MBL can collect continuous data over an extended period of time. For example, students might gather data about variation in the temperature of their classroom over five consecutive days. They can then determine if it is warmer on sunny days, if the classroom is equally warm when there are people in it and when there are not, if the temperature of the classroom changes at night, or if there are patterns in the variations.

Measure events that happen very quickly. Some events happen too quickly for the human eye to observe in detail. Motion is an example of this. We can observe a ball rolling down a ramp, but the event happens so quickly that we are unable to note variation in the speed of the ball. The distance probe can create a graphic representation of the event that will provide evidence of any variation in speed.

Measuring events indirectly. The MBL can help students to obtain data that are difficult to gather. As part of a study of human physiology, students may be given the task of gathering data about pulse rate. This is not easy to do accurately. An alternative to counting pulse at the wrist is to use a small light probe designed specifically to gather pulse data. This probe clips onto the ear lobe and records data about changes in the amount of light able to pass through the lobe caused by the pulsing of blood in the tissue. While the resulting graph actually is a record of variation in light, the data is reinterpreted to determine pulse rate. In this way, it is possible for children to "see" what cannot be seen.

Measuring events that change over a very small range. Changes in temperature or light may be too subtle for our senses to notice. When students gather this kind of data with MBL, they can enlarge the scale so that changes can be noted. For example, students investigating solar energy are able to use the MBL to discover how different building materials affect the heating and cooling of model houses. While variation in temperature range may be only a degree or two, this is significant when choosing a design and material for a house.

The power of the MBL to show change over time is significant. Here the MBL allows elementary teachers and students access to the concepts behind change over time without having to use the abstract mathematical representations. In fact, many researchers are now looking at the importance of introducing students to these concepts informally, before they encounter the abstract mathematics.

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Microcomputer-Based Laboratories (continued)

Technical Background for MBL

Understanding your tool is important for designing experiments and for intelligently analyzing the data it provides. When one is a beginner, there is a tendency to believe that whatever the technological tool says must be the truth. Learning to be an intelligent user is part of becoming technologically literate.

Most MBL probes consist simply of a receptor that is sensitive to a particular signal, such as light or heat. The signal received by the sensor is then translated into a form understandable by the computer and displayed on the screen in either table or graph form. Thus there are three steps, each one carried out by a different component:

1. detection done by a sensor or probe,
2. transformation of the detected signal to computer-readable form done by circuitry and transistors, usually contained in an interface box between the sensor and the computer; and
3. display of the data in table and graph form done by the software.

The motion probe is different in one regard from the above description: in addition to a sensor there is an emitter. The probe sends out an ultrasonic sound pulse and listens for the echo. This is analogous to the process commonly used by bats to find their way and catch insects.

Calibration is an important step when using the temperature and light probes. This is done using a calibration option within the MBL software menu. For the HRM temperature probe, the screen instructions tell you to place the probe first in hot water and then in cold and enter the actual temperature of each as read from a hand-held thermometer. For the PSL probes, you are instructed to enter the calibration number shown on a tag attached to the probe cable.

Without calibration the data would correctly show differences in temperature between the hot and cold water, but not necessarily the correct temperatures.

Beyond this general description of MBL probes, it is important to understand the specific characteristics of each type and make of probe. For instance, the range and the response time of the temperature probe. For the activities included in this manual, the temperature range needs to be from freezing to boiling, from 0° to 100°. Response time refers to how long the probe needs before it is reading the correct temperature. Keeping a thermometer in your mouth for three minutes when measuring your own temperature is an example of allowing for response time. In general there is a trade-off between ruggedness and response time: a metal-encased temperature probe is much sturdier but requires a longer time to reach equilibrium.

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Microcomputer-Based Laboratories (continued)

Finally, using a probe is using a tool, and as with any tool, it is possible to use it incorrectly. For a temperature probe, you need to know where the sensor is located on the probe and ensure that this part is in good contact with the object being measured. With the motion probe, it is important to ensure there is a clear path for the sound pulse. The software only responds to the first echo received, and if this is from a chair or other obstacle along the path, the graph will flatten out as if the moving object has stopped even though it is continuing to move beyond the obstacle.

Products and Vendors

AccuLab Products Group, LEW & Associates. *SensorNet Interface and Probes for the Macintosh.* 200 California Avenue, Suite 217, Palo Alto, CA 94306-1618. 415-325-5898.

Broderbund Software. *Broderbund Science Tool Kit.* 17 Paul Drive, San Rafael, CA 04903-2101.

IBM Corporation. *Personal Science Laboratory Explorer Software.* Products available through your local IBM marketing representative. Call 800-IBM-2468 ext 999.

National Geographic Society. *National Geographic Kids Network Telecommunications-Based Science Curricula for Grades 4–6.* 1-800-368-2728 for catalog and orders.

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Vernier Software. *Universal Lab Interface for Macintosh, Probes and Software for Apple II and IBM.* 2920 S. W. 89th Avenue, Portland, OR 97225.

William K. Bradford. *Exploring Matter through Lessons and Labs, Exploring Heat through Lessons and Labs.* Apple II software and probes. 310 School Street, Acton, MA 02170. 800-421-2009.

Wings for Learning. *Bank Street: Voyage of the Mimi,* an integrated curriculum with software and hardware. 1600 Green Hills, P.O. Box 660002, Scotts Valley, CA 95067-0002. 800-321-7511.

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Resources for Elementary Teachers

Beyond Drill and Practice: Expanding the Computer Mainstream. A Guide for Teachers who Want to Expand the Rse of the Computer as a Learning Tool with Students, Especially those with Special Learning Needs. Reston, VA: Council for Exceptional Children. 703-620-3660.

By TERC. A list of products developed by TERC for hands-on math and science education K–college. TERC, 2067 Massachusetts Avenue, Cambridge, MA 02140, Internet: Peggy_Kapisovsky@TERC.edu.

Delta Education: Hands-On Science and Hands-On Math catalogs. Mail order catalog of kits and manipulatives. Delta Education, Inc. P.O. Box 950, Hudson, NH 03051. 800-442-5444.

Edmund Scientific Catalog. Mail order catalog of kits and equipment for elementary and secondary. 101 East Gloucester Pike, Barrington, NJ 08007-1380. 609-547-8880.

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Forte Company. Source for the Drops Cylinder and other science equipment. 194 Shelley Avenue, Campbell, CA 95008. 408-559-3180.

Hands On! A semi-annual publication of TERC projects that highlights new and ongoing research and development in hands-on math and science education. Senior Editor: Peggy Kapisovsky, TERC, 2067 Massachusetts Avenue, Cambridge, MA 02140. Internet: Peggy_Kapisovsky@TERC.edu.

"State Policies on Science and Math Education: 1992" from Melanie Dalkilic, CCSSO, One Massachusetts Avenue, NW, Suite 700, Washington, DC 20001-1431. $5 per copy

Teacher's Laboratory. Mail order books and materials for elementary teachers. P.O. Box 6480, Brattleboro, VT 05302-6480. 802-254-3457. FAX 802-254-5233

Used Numbers: Real Data in the Classroom. Counting: Ourselves and Our Familiies, Sorting: Groups and Graphs, Measuring: From Paces to Feet, Statistics: The Shape of the Data, Statistics: Middles, Means, and In-Betweens. Mathematics curriculum for grades K–6. Palo Alto: Dale Seymour Publications. 800-872-1100.

Resources for Telecommunications

America OnLine. A commercial telecommunications network used by the Hands-On Elementary Science project and LabNet project at TERC. Free software, $9.95 per month for 5 hours unlimited online time. Call 1-800-827-6364 to order.

ACCESS ERIC, 1600 Research Boulevard, Rockville, MD 20850.

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NetTEACH News. Editor: Kathleen M. Rutkowski, 13102 Weather Vane Way, Herndon, VA 22071. Internet: kmr@cnri.reston.va.us.
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State-by-state directory of library catalogs accessible through the Internet. Also includes instructions for accessing campus-wide information systems and dial-up libraries. For information, contact Art St. George, Executive Network Services Officer, Universtiy of New Mexico, (505) 277-8046. Internet: stgeorge@bootes.unm.edu

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